(19) Europäisches Patentamt
European Patent Office
Office européen des brevets

(11) EP 1 115 217 A2

(12) EUROPEAN PATENT APPLICATION

(43) Date of publication:
11.07.2001 Bulletin 2001/28

(51) Int Cl.[7]: **H04B 7/26**

(21) Application number: **01300036.9**

(22) Date of filing: **04.01.2001**

(84) Designated Contracting States:
AT BE CH CY DE DK ES FI FR GB GR IE IT LI LU MC NL PT SE TR
Designated Extension States:
AL LT LV MK RO SI

(30) Priority: **07.01.2000 US 175155 P**
15.12.2000 US

(71) Applicant: **LUCENT TECHNOLOGIES INC.**
Murray Hill, New Jersey 07974-0636 (US)

(72) Inventors:
- **Chang, Kirk K.**
Morganville, New Jersey, 07751 (US)
- **Hernandez-Valencia, Enrique**
Chicago, Illinois, 60629 (US)
- **Luo, Wei**
Eatontown, New Jersey, 07724 (US)
- **Nanda, Sanjiv**
Clarksburg, New Jersey, 08510 (US)

(74) Representative:
Watts, Christopher Malcolm Kelway, Dr. et al
Lucent Technologies (UK) Ltd,
5 Mornington Road
Woodford Green Essex, IG8 0TU (GB)

(54) A method for interleaving of full rate channels suitable for half duplex operation and statistical multiplexing

(57) A time division multiplexed communications method and system in which time is divided into a number of frames and each frame is divided into N data bursts. The method and system further has a first multiplexer by which a half rate channel is formed as a series of bursts that occur periodically every N bursts once per frame, a second multiplexer in which a full rate channel is formed as two half rate channels on consecutive timeslots, and a transmitter transmitting the full rate channel from a first wireless station to a second wireless station. The full rate channel provided by two half rate channels on consecutive timeslots yields a significantly larger resource pool available for assignment of communication traffic. For full rate channels, the interleaving 0246/1357 method that is used by the system is just as good as the known 0123/4567 method when ideal frequency hopping is used, and the 0246/1357 method performs better when non-ideal frequency hopping or no frequency hopping is used.

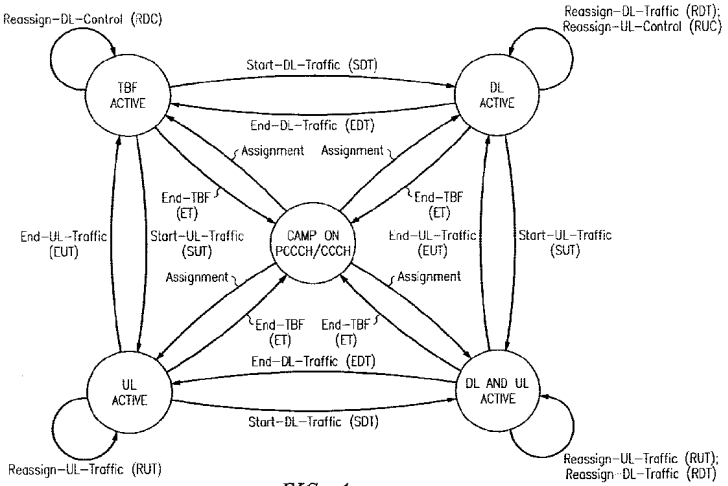

FIG. 4

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Description

Technical Field

[0001] The invention relates to relates generally to wireless communication networks and, more particularly, to a method and system for efficiently providing voice communications over wireless and/or cellular networks while using full rate channels.

Description of the Prior Art

[0002] The widespread growing popularity of the Internet has encouraged wireless communication system developers to continually improve the data communication capabilities of their systems. In response to this need, various standards bodies have formulated and continue to formulate new third generation (3G) standards which support higher data rates. For example, standards organizations such as the European Telecommunications Standards Institute (ETSI), the Association of Radio Industries and Broadcasting (ARIB) and the Telecommunications Industry Association (TIA) are continually developing standards to support faster and more efficient wireless communications.

[0003] Similarly, the wireless communications industry is often developing and implementing new wireless transmission protocols which provide faster, more robust and more efficient data communications over air interfaces. For example, GSM continues to evolve. In another example, general packet radio service (GPRS) has been developed as a packet-switched upgrade for the well known time division multiple access (TDMA) system. In a further advancement in the art, enhanced GPRS (EGPRS) has also been developed.

[0004] Presently, GSM, GPRS and EGPRS physical layers have the following characteristics: a carrier that consists of two 200 kHz bandwidth segments of the allocated GSM spectrum, 45 MHz apart, one for the downlink and one for the uplink; time is divided into frames with a multiframe comprising 52 frames and spans 240 msec.; each frame consists of 8 time slots; one slot on one carrier is referred to as a GSM channel; there is a one-to-one correspondence between a slot (numbered j, j=0,... 7) on a downlink carrier at frequency (f) and an uplink slot (numbered j) on the corresponding uplink carrier (f+45 MHz); a transmission in a slot is referred to as a burst; and a block consists of a predefined set of four bursts on the same slot.

[0005] Radio access bearers are currently being designed in order to provide real time services in EGPRS Phase II. However, recent approaches rely on using the existing burst based random access channels on the uplink and block based assignment channels on the downlink. Each block is interleaved and transmitted over 4 bursts (20 msec). However, investigation has shown systems based on 20msec granularity require at least a 60 msec delay budget. Also, the investigation has shown transmission of assignments to multiple mobile stations within a single 20 msec message often is inefficient due to low packing and is incompatible with interference reduction techniques such as smart antennas and power control. As a result, block based assignment channels according to the recent approaches can result in excessive control overhead and excessive delays for statistical multiplexing of real time transfers (e.g. voice talkspurts). It is desirable to provide a better access and assignment system and method.

[0006] In order to efficiently use the high capacity of a wireless or a cellular data telecommunication system (e.g., GPRS or EGPRS), it is also desirable to provide voice and data multiplexing capability as well as statistical multiplexing of voice users. Currently these cellular data telecommunication systems are designed to provide primarily non-real time (delay insensitive) data services. Conversational speech and other real time interactive communications are delay sensitive and require the design of new control mechanisms to provide fast control channels to meet the critical delay requirements. Therefore, there is a need to redesign wireless data telecommunication systems to provide such control capabilities to make them suitable for multiplexing both non-real-time services and real-time services, such as conversational speech.

[0007] Presently under GSM, a mobile user assigned to some channels has to receive on even bursts in one multiframe and odd-bursts in the next multiframe. Such switching between even and odd bursts is not well suited for dynamic assignment of uplink and downlink channels. Therefore, there is a need to redesign wireless data telecommunication systems to provide different burst-channel structures that are suited to dynamic assignment of uplink and downlink channels. A redesign for half rate channels and especially for full rate channels. Present full rate channel structure can be very wasteful of available bandwidth and delay times by using the present channel structures and present interleaving.

Summary of the invention

[0008] This need is met by the method of the present invention wherein systems and methods are described that enable efficient and flexible multiplexing of both real-time and non-real-time services over full rate channels of wireless data telecommunication systems.

[0009] Briefly stated in accordance with one aspect of the invention, the aforementioned problems are addressed and an advance in the art achieved by providing a system for communicating using wireless time division multiplexed communications in which time is divided into a plurality of frames and each frame is divided into *N* data bursts. This system includes a first multiplexer defining a half rate channel as a series of bursts that occur periodically every N bursts once per frame, a second multiplexer for defining a full rate channel as two consecutive half rate channels; and a transmitter transmitting the full rate channel from a first station to a second station.

[0010] In accordance with a specific aspect of the invention, the aforementioned problems are addressed by providing a system for communicating using wireless time division multiplexed communications in which time is divided into a plurality of frames and each frame is divided into *N* data bursts. This system includes a first multiplexer defining a half rate channel as a series of bursts that occur periodically every N bursts once per frame, a second multiplexer for defining a full rate channel as two consecutive half rate channels; and a transmitter transmitting the full rate channel from a first station to a second station. The system also includes an interleaver which interleaves bursts using 0246/1357 interleaving.

[0011] In accordance with another specific aspect of the invention, the aforementioned problems are addressed by providing a method for communicating using wireless time division multiplexed communications in which time is divided into a plurality of frames and each frame is divided into *N* data bursts. This method includes the steps of interleaving bursts using a 0246/1357 sequence to provide a plurality of half rate channels, using two consecutive half rate channels of the plurality of half rate channels to provide a full rate channel, and transmitting the full rate channel made up of the interleaved bursts from a first station to a second station.

Brief Description of the Drawing

[0012] FIG. 1 is a block diagram of a GERAN system with mobile station receiver-transmitters and a central base station receiver-transmitter.

[0013] FIG. 2 illustrates the user plane protocol stack for Pre-GERAN and GERAN systems.

[0014] FIG. 3 illustrates two multiframes each of which is divided into four channels of various types.

[0015] FIG. 4 illustrates a state diagram for a system in accordance with the invention.

[0016] FIG. 5 illustrates a state table that is another way of presenting the information of FIG. 4.

[0017] FIG. 6 illustrates a RT TBF State Diagram in table form.

[0018] FIG. 7 illustrates message and uplink interaction in tabular form.

[0019] FIG. 8 illustrates a summary of downlink signaling and control messages in tabular form.

[0020] FIG. 9 illustrates downlink burst message content in tabular form.

[0021] FIG. 10 illustrates uplink burst message content in tabular form.

[0022] FIG. 11 illustrates the temporary block flow of messages between a mobile station and a base station of a network using GARAN techniques during a start uplink traffic procedure.

[0023] FIG. 12 illustrates the temporary block flow of messages between a mobile station and a base station of a network using GERAN techniques during an end uplink procedure.

[0024] FIG. 13 illustrates the temporary block flow of messages between a mobile station and a base station of a network using GERAN techniques during a start downlink procedure.

[0025] FIG. 14 illustrates the temporary block flow of messages between a mobile station and a base station of a network using GERAN techniques during an end downlink procedure.

[0026] FIG. 15 illustrates the temporary block flow of messages between a mobile station and a base station of a network using GERAN techniques during a reassign uplink traffic channel procedure.

[0027] FIG. 16 illustrates the temporary block flow of messages between a mobile station and a base station of a network using GERAN techniques during a reassign downlink traffic channel procedure.

[0028] FIG. 17 illustrates the temporary block flow of messages between a mobile station and a base station of a network using GERAN techniques during a reassign uplink control channel.

[0029] FIG. 18 illustrates the temporary block flow of messages between a mobile station and a base station of a network using GERAN techniques during a reassign downlink control channel procedure.

[0030] FIG. 19 illustrates the temporary block flow of messages between a mobile station and a base station of a network using GERAN techniques during an ET procedure to terminate a TBF.

[0031] FIG. 20 shows a multiframe diagram which is very similar to FIG. 3 showing known a GSM half-rate traffic channel structure.

[0032] FIG. 21 illustrates a multiframe diagram very similar to FIG. 20, showing a new GERAN half rate traffic channel structure according to the present invention.

[0033] FIG. 22 is a diagram illustrating downlink assignments according one communication technique of the invention.

[0034] FIG. 23 is a diagram illustrating downlink assignments according to another communication technique of the

invention

[0035] FIG. 24 is a diagram illustrating downlink assignments similar to FIG. 22 but with different loading.

[0036] FIG. 25 is a diagram illustrating downlink assignments similar to FIG. 23 but with different loading.

[0037] FIG.26 is a diagram illustrating half rate bursts on which a downlink talkspurt may start for a Class 1 mobile station.

[0038] FIG. 27 is a diagram illustrating half rate bursts on which a downlink talkspurt may start for a Class 1 mobile station under different conditions than FIG. 26.

[0039] FIG. 28 is a table that shows the speech frame arrivals and play out instants with different interleaving approaches.

[0040] FIG. 29 is a table showing performance of two interleaving schemes with QPSK modulation.

[0041] FIG.30 is a diagram illustrating full rate bursts on which a downlink talkspurt may start for a Class 1 mobile station.

[0042] FIG. 31 is a diagram illustrating full rate bursts on which a downlink talkspurt may start for a Class 1 mobile station under different conditions than FIG. 28

Detailed Description

[0043] Referring now to FIG. 1, a system 1 is shown. System 1 in a preferred embodiment, is a GSM Enhanced-General-Packet-Radio-Service Radio Access Network (GERAN) as described herein. GERAN 1 has a central or base station 12 which has a transmitter, a receiver and an antenna (not shown) as a base station typically has. Base station 12 is part of the GERAN 1. GERAN 1 is used to communicate with and carry message traffic between a caller on a mobile station 20, and in a preferred embodiment to callers of all kinds and mobile stations, such as mobile stations 20, 30. The base station 12 has a transmitter 13 and a receiver 17. Transmitter 13 has multiplexers 14 and 15 that multiplex the speech and/or data traffic to form channels and subchannels for transmitting. Receiver 17 has corresponding demultiplexers 18 and 19 to demultiplex speech and/or data received from other stations. With present time division multiplexing techniques multiplexers 13 and 14 could be the same unit, and similarly demultiplexers 18 and 19 could be in the same unit. To take full advantage of the present invention, mobile stations 20 and 30 have compatible multiplexing and demultiplexing functions. Further, the present invention provides new traffic and control channels that are completely compatible with beam forming and power control techniques, enabling their use for all new traffic and control channels.

[0044] The present invention has unidirectional traffic and control channels. The benefits of statistical multiplexing are achieved through the application of the following principles. All new control and traffic channels are unidirectional, with independent frequency and slot allocation in the uplink and downlink directions. Available resources can be dynamically allocated as necessary to traffic and control channel functions. This allows for maximum flexibility in allocation of available resources.

[0045] In previously known GSM, GPRS and EGPRS Phase 1, a multiplexer defined a channel to consist of one time slot on a 200 kHz carrier at frequency *f* for the downlink *and* a *corresponding* slot on a 200 kHz carrier at (*f*+ 45 MHz) on the uplink. Breaking this historical association between uplink and downlink channels allows for statistical multiplexing of speech, in particular, since the uplink and downlink resource demands occur independently. Breaking the historical association between uplink and downlink maximizes the resource pool available for assignment when new data or speech becomes available for transmission.

[0046] A primary consideration for any GERAN method and system must be the impact on half-duplex mobiles, given their cost advantages. (Half duplex mobiles in TDMA systems transmit and receive in different time slots and therefore do not require a duplexer). In the previous GSM, GPRS and EGPRS Phase 1, corresponding time slots on the uplink and downlink were chosen in such a way that they were compatible with half-duplex operation. With statistical multiplexing, the system can be specifically design for maximum flexibility of operation with half duplex mobiles, when both the uplink and downlink time slots are dynamically assigned The new control and traffic channels are designed to support half-duplex mobiles in a manner that maximizes the pool of traffic and control channel resources available for assignment to these mobiles.

[0047] In what follows, a method for interleaving of half rate channels suitable for half duplex operation and statistical multiplexing. According to the present invention, an alternative (0246/1357) burst interleaving for half rate channels was found to offer the following advantages: larger resource pools for statistical multiplexing under half duplex constraints imposed by mobile station class; lower delay to the start of a talkspurt; and better link level performance when there is no frequency hopping or when frequency hopping is non-ideal.

[0048] The ability to multiplex and transmit voice and data and the play out delays for speech were found to be equivalent for both the known (0123/4567) interleaving method and the (0246/1357) interleaving method of the present invention.

Application of Interleaving of Both Half Rate and Full Rate Channels Suitable for Half Duplex Operation to GERAN (GSM EDGE (Enhanced General Packet Radio Service)

Radio Access Network)

GERAN document 2E99-584 in pertinent part reads:

[0049] The GERAN description describes the key new ideas needed to introduce statistical multiplexing of all bearer classes on the GERAN air interface for delivery over the packet-switched network. It focuses only on the support of overall UMTS service requirements, and does not address network architecture issues or circuit-switched services.

[0050] The central new service requirement for GERAN (compared to EGPRS Phase 1) is the support of speech service using the packet-switched backbone network. The focus of the document is the definition of new traffic and control channels to support statistical multiplexing of speech, real-time data, and non-real-time data, and the corresponding new MAC procedures that are needed to guarantee QoS.

List of Acronyms used herein

[0051]

AMR	Adaptive Multi-Rate
ARI	Access Request Identifier
BCCH	Broadcast Control Channel
BEP	Bit Error Probability
BFACCH	Burst-based FACCH
CCCH	Common Control Channel
CID	Carrier Identifier
CTS	Carrier Time Slot
DBMCH	Downlink Block Message Channel
DFACCH	Dim-and-Burst FACCH
DMT	Downlink (Burst) Message Type
DPRCH	Downlink Periodic Reservation Channel
DTCH/FS	Downlink Traffic Channel for Full Rate Speech
DTCH/HS	Downlink Traffic Channel for Half Rate Speech
DTCH/FD	Downlink Traffic Channel for Full Rate Data
DTCH/HD	Downlink Traffic Channel for Half Rate Data
EDT	End Downlink Traffic
EEP	Equal Error Protection
EGPRS	Enhanced General Packet Radio Service
EUT	End Uplink Traffic
FACCH	Fast Associated Control Channel
FACKCH	Fast Acknowledgment Channel
FASSCH	Fast Assignment Channel
FFS	For Further Study
FR	Full-Rate
FRACH	Fast Random Access Channel
GERAN	GSM/EDGE Radio Access Network
HR	Half-Rate
IP	Internet Protocol
L1	Layer 1 (Physical Layer)
MAC	Medium Access Control
MCS	Modulation and Coding Scheme
MR	Measurement Report
MS	x Mobile Station
MSACCH	Modified Slow Associated Control Channel
NRT	Non-Real Time
OFF	Offset in Frames
PBCCH	Packet Broadcast Control Channel
PCCCH	Packet Common Control Channel

PDCP	Packet Data Convergence Protocol
PH	Phase
QoS	Quality of Service
RAB	Radio Access Bearer
RAN	Radio Access Network
RDC	Reassign Downlink Control
RDT	xReassign Downlink Traffic
RLC	Radio Link Control
RR	Radio Resource Management
RRBP	Relative Reserved Burst Period
RT	Real Time
RTP	Real Time Protocol
RUC	Reassign Uplink Control
RUT	Reassign Uplink Traffic
SACCH	Slow Associated Control Channel
SD	Start Delay
SDT	Start Downlink Traffic
SID	Silence Descriptor
SUT	Start Uplink Traffic
TBF	Temporary Block Flow
TBFI	Temporary Block Flow Identifier
TCP	Transport Control Protocol
TFI	Temporary Flow Identifier
TS	Time Slot
UDP	User Datagram Protocol
UEP	Unequal Error Protection
UBMCH	Uplink Block Message Channel
UPRCH	Uplink Periodic Reservation Channel
UMT	Uplink (Burst) Message Type
UMTS	Universal Mobile Telecommunications System
USF	Uplink State Flag
UTCH/FS	Uplink Traffic Channel for Full Rate Speech
UTCH/HS	Uplink Traffic Channel for Half Rate Speech
UTCH/FD	Uplink Traffic Channel for Full Rate Data
UTCH/HD	Uplink Traffic Channel for Half Rate Data
UTRAN UMTS	Terrestrial Radio Access Network
VAD	Voice Activity Detection

Service Requirements

[0052] Service requirements for GERAN are based on those of UMTS, with the addition of an optimized speech service based on GSM/AMR. These requirements describe the radio bearer classes, the need for parallel bearer flows, handover, and alignment with UMTS core network. Specific error, throughput, and delay requirements for each bearer class are FFS, but range of capabilities is clear from current UMTS requirements.

Support of Radio Bearer Classes in Alignment with UMTS

[0053] The UMTS radio bearer classes for conversational, streaming, interactive, and background services cover a range of real-time and non-real-time data services with a wide range of error, throughput, and delay requirements. The GERAN requirements for these services will be aligned with UMTS with adjustments as necessary to capture unique characteristics of the GERAN.

[0054] Voice service requirements are based on those of GSM/AMR. A GERAN radio bearer class will be specifically optimized for voice service.

Support for Parallel Bearer Flows with Different QoS

[0055] The GERAN shall support up to three parallel bi-directional bearer flows with different QoS requirements. This capability will enable support of simultaneous voice and data service as well as multimedia service.

Handover Requirement for RT Services

[0056] Voice and real-time data services have QoS characteristics not supported by existing EGPRS reselection procedures. The GERAN shall include procedures to support maintenance of acceptable (TBD) QoS during network-assisted handover procedures for voice and real-time data services. The details of these handover procedures are outside the scope of this document.

Alignment with UMTS Core Network

[0057] The GERAN shall conform to the core network interface requirements established for UMTS with only those changes necessary to adapt to unique characteristics of the GERAN. In particular, this requires that the GERAN provide the Iu-ps interface to the UMTS core network.

Targeted Configuration

Blocking Limited Deployment

[0058] This concept proposal is optimized for blocking limited deployment, where the greatest capacity is achieved by utilizing available traffic-carrying channels to the fullest degree. In a blocking limited deployment, traditional circuit channels for delivery of voice and real-time data services are inefficient due to significant periods of "dead time" during a typical flow. For voice service with a voice activity factor approximately 40%, there is considerable potential to increase overall capacity with statistical multiplexing of traffic channel resources.

Interference Limited Deployment

[0059] Since an interference-limited system must operate at some fraction of its channel capacity to achieve acceptable aggregate performance, statistical multiplexing typically offers little or no capacity advantage. However, interference-limited deployment (e.g. 1/3 reuse) becomes blocking limited with techniques like beam forming and power control. It is more appropriate to optimize the GERAN for deployment configurations that take advantage of the application of the latest interference management techniques, which make them more blocking limited. This approach assures that the greatest capacity benefits are available in all configurations.

Less Aggressive Reuse (e.g. 4/12) Preferred when Spectrum Available

[0060] Blocking limited deployment is and will be common for the foreseeable future. Blocking limited deployment is preferred in areas not limited by availability of spectrum. It is also preferred in areas where uniform quality of service is a requirement, since coverage "holes" become more common when operating in interference limited conditions.

All New Traffic and Control Channels

[0061] This invention introduces new traffic and control channels that are completely compatible with beam forming and power control techniques, enabling their use for all new traffic and control channels. This is achieved by designing all communication on these channels to be point-to-point. There are no multicast or broadcast control messages or control fields in any downlink transmissions.

Multiplexing Principles

[0062] The benefits of statistical multiplexing are achieved through the application of the following principles.

Unidirectional Traffic and Control Channels

[0063] All new control and traffic channels are unidirectional, with independent frequency and slot allocation in the uplink and downlink directions. Available resources can be dynamically allocated as necessary to traffic and control channel functions. This allows for maximum flexibility in allocation of available resources. Breaking the historical association between uplink and downlink channels is necessary for statistical multiplexing of speech, in particular, since the uplink and downlink resource demands occur independently. Breaking the association between uplink and downlink maximizes the resource pool available for assignment when new data or speech becomes available for transmission.

[0064] A primary consideration for any new GERAN concepts must be the impact on half-duplex mobiles, given their

cost advantages. The new control and traffic channels are specifically designed to support half-duplex mobiles in a manner that maximizes the pool of traffic and control channel resources available for assignment to these mobiles.

EGPRS Phase 1 and Phase 2 Traffic on Different Time Slots

[0065] Because of the need to allocate uplink and downlink channels independently, it is not possible to multiplex EGPRS Phase 1 and Phase 2 (GERAN) traffic on the same time slot. This traffic must be segregated onto separate time slots at any one time.

Multiplexing Different QoS Classes

[0066] This proposal supports the multiplexing of all QoS classes onto the same channels. The same uplink an downlink resource pools are shared among all flows, regardless of their QoS class, maximizing the advantages of statistical multiplexing.

Operation of TBF Establishment

[0067] The concept of a Temporary Block Flow (TBF) of GPRS/EGPRS is enhanced in the GERAN to have a unique profile with direction, QoS, and protocol attributes.

Negotiation of TBF Profile

[0068] Before establishment of any TBF between a mobile and the network, it camps on the CCCH or PCCCH in the current cell, and is governed by procedures currently defined in EGPRS. When the first TBF is established, its attributes are defined as follows:

[0069] The TBF is either unidirectional (uplink or downlink) or bi-directional. A voice TBF would typically be bi-directional. A data TBF could be either unidirectional or bi-directional. Data traffic requiring any significant exchange, such as upper layer acknowledgments, could be bi-directional, thus saving the overhead of repeated TBF establishment for periodic traffic. The TBF is assigned QoS attributes consistent with the desired service quality and bearer class. Given the assigned QoS attributes, the TBF may also be eligible for network-directed handover procedures to minimize service disruption while switching between two cells.

[0070] The TBF is assigned protocol attributes. For example, for voice service the TBF uses physical layer channel coding optimized for voice, and eliminates headers associated with other protocol layers. Data services will typically require physical layer channel coding optimized for data and the presence of the headers for all protocol layers to control more complex protocol functions.

MAC Procedures for Established TBF

[0071] Once the first TBF is established, the mobile remains on the new RT traffic and control channels, regardless of the presence or absence of data to send, until all TBFs for the mobile are released. Each TBF remains valid regardless of activity until it either times out or is explicitly released by the network.

Channels for Fast Resource Assignment

[0072] When there is no data transfer in the downlink direction (no downlink traffic channel is assigned to the TBF), the mobile must monitor a common downlink control channel for fast resource assignment directives. These assignment directives assign traffic channel resources to the TBF as needed to support data transfer with the agreed-to QoS attributes.

[0073] When the TBF has an active downlink traffic channel assignment, it typically monitors the same physical channel for fast associated control channel messages with alternative assignment directives. As an alternative for mobiles with adequate multi-slot capability, the mobile may be required to monitor both the downlink traffic channel for user data and a common downlink control channel for fast assignment directives.

[0074] When a mobile has more than one TBF active in the downlink direction, it may be required to monitor either a common downlink control channel and/or one (or more) of the downlink traffic channels for fast assignment directives.

Traffic Channel Assignment

[0075] When the TBF requires a downlink traffic channel for data transfer, the network sends a fast assignment

directive to the mobile to allocate a downlink traffic channel for the data transfer.

[0076] When the TBF requires an uplink traffic channel for data transfer, the mobile sends a fast access request on an uplink fast access control channel. The network responds with a fast assignment directive to allocate the necessary uplink resource.

[0077] In all cases, since QoS and protocol attributes have been negotiated during establishment of the TBF, there is no ambiguity as to the parameters of the resource request or assignment. These attributes do not change from one resource request or assignment to the next during a TBF.

Timing Alignment and Power Control

[0078] For as long as a mobile has at least one TBF established, it remains in timing alignment and under power control. This allows for all access bursts to be of normal length, since abbreviated bursts are not needed to allow for misalignment. This also avoids the extra overhead of performing these functions at the beginning of each traffic channel assignment.

Protocol and Architecture

[0079] To support optimized speech, RT and NRT users over packet bearer, two different protocol stacks are proposed to meet the requirements of optimized speech and data bearers, as shown in FIG. 2.

[0080] The protocol stack used for a particular TBF is negotiated at the TBF setup along with the QoS attributes. For optimized speech bearer, a dedicated unidirectional traffic channel is allocated to a speech TBF during a talk spurt. Hence no RLC/MAC header is used. The IP/UDP/RTP header information is exchanged at speech TBF setup and is, therefore, eliminated from the speech frame transmission over the RF interface. So, the entire shaded area of the protocol stack is dispensed with for optimized speech users, but not for RT and NRT data users. For RT and NRT data users, the EGPRS Phase 2 protocol stack is kept. Possible optimization for RT data bearers is FFS.

RLC

[0081] The GERAN will reuse the EGPRS Phase 1 RLC with only those extensions needed to adapt RLC procedures to the new RT traffic and control channels.

MAC

[0082] The RT MAC is new for the GERAN, based on the fast access and assignment procedures of this proposal.

Radio Interface Aspects

[0083] The GERAN Layer 1 is an enhanced version of the EGPRS Phase 1 Layer 1. Enhancements are related to the introduction of new types of traffic and control channels, as described below.

Traffic Channel Design

[0084] All traffic channels in GERAN are considered to be *unidirectional* channels. Chain interleaving is done on speech traffic channels and block interleaving for data. Half-rate traffic channels use alternate bursts. This has a significant multiplexing advantage for half-duplex mobiles. In the case of NRT data, it permits ease of multiplexing with RT data and voice.

[0085] Speech, RT and NRT users may share a time slot by being assigned to two different half-rate channels on the same slot. A half-rate or a full-rate traffic channel is allocated to a specific speech or data user for the duration of a talk spurt or "data spurt". *No* headers or stealing bits are required for the receiver to distinguish between these traffic channels. For data channels, stealing bits and header formats are used as in EGPRS Phase I, but the USF is eliminated on the downlink.

[0086] All traffic channel assignments are through messaging on the new control channels (including TCH associated control channels).

Speech Traffic Channel Design Principles

[0087] Speech traffic channels are based on supporting the GSM/AMR modes on full-rate and half-rate channels. The full-rate channel coding for the GSM/AMR modes is the same as in current GSM/AMR. The channel coding for

half-rate AMR modes will be based on either 8PSK or QPSK modulation, depending on the results of separates studies.

Interleaving

[0088] Interleaving in all cases will be chain interleaving over 40 msec, as in GSM/AMR. For a full-rate traffic channel the interleaving is over 8 radio bursts in 40 msec, with a chaining overlap of 4 radio bursts in 20 msec. For a half-rate traffic channel, the interleaving is over 4 radio bursts spaced over 40 msec, with a chaining overlap of 2 radio bursts in 20 msec. This half-rate interleaving mode is sometimes described as 0246/1357, to describe the use of alternate bursts for each of two half-rate channels over the 8 bursts in a 40 msec interval. The alternative of block interleaving of 2 speech frames over 4 consecutive bursts in 20 msec intervals alternating between two half-rate channels is sometimes called 0123/4567 interleaving.

Compatibility with Half-Duplex Mobiles

[0089] Half-duplex mobiles typically have severe constraints on the combination of uplink and downlink channels that they can support. This is an important consideration since statistical multiplexing works more efficiently with a larger pool of resources available for allocation. Investigation has shown that the best statistical multiplexing efficiency is achieved for half-duplex mobiles by defining all half-rate traffic and control channels to use no more than every other burst on any one time slot. This burst allocation for half-rate speech channels is discussed below.

Headers

[0090] Since the entire channel (either full-rate or half-rate) is dedicated to a TBF for the length of a talk spurt, there is no need for additional header beyond what is in existing GSM/AMR.

Half Speech Block

[0091] With chain interleaving, half of the information transmitted in the first and last 20 msec intervals of a talk spurt is typically unusable. Since AMR has multiple compatible modes of operation with different sizes of speech frames every 20 msec, it is possible to define new channel coding for these currently unused bits to transmit special speech frames. For example, with the 7.4 kbps mode of operation, it is possible to specify alternative channel coding on the first block of unused bits to encode a single 4.75 kbps speech frame. The performance of this *half speech block* is somewhat worse than the performance of the remaining speech frames, but the overall impact on the quality of a typical talk spurt is small.

[0092] Use of the half speech block reduces the delay to the beginning of a talk spurt by 20 msec. By starting a talk spurt with a half speech block, the overall time on the traffic channel is also reduced by 20 msec (corresponding to the first 20 msec interval typically needed to start up a chain interleaving sequence. By using a half speech block for the last speech frame of a talk spurt, which is relatively unimportant to the intelligibility of the talk spurt, the overall time on the traffic channel is reduced by an additional 20 msec (for a total of 40 msec). This is accomplished by eliminating the need to transmit the last 20 msec portion of the last valid speech frame.

[0093] The half speech block could also be used in the middle of a talk spurt to free up room to transmit a frame of control information. This is called "dim-and-burst" signaling as opposed to "blank-and-burst" signaling, which replaces an entire speech frame with a frame of control information. This "dim-and-burst" concept is introduced as a new associated control channel below.

Initial Burst of a Talk Spurt

[0094] In GSM, interleaving must begin on a radio block boundary, which occurs every 20 msec. Since every talk spurt is specifically assigned to a traffic channel, it is not necessary to maintain this 20 msec granularity. Allowing a talk spurt to begin on any burst improves the average delay to the beginning of a talk spurt by approximately 5 msec for half-rate channels, since the assignment granularity is reduced from 20 msec to 10 msec. The average improvement for full-rate channels is approximately 7.5 msec, since the assignment granularity is reduced from 20 msec to 5 msec.

AMR VAD and Hangover

[0095] The current AMR VAD and hangover interval are not designed to provide optimal performance in a system with statistical multiplexing of speech. They are both candidates for further study to reduce the average length of talk spurts without significantly increasing the rate of occurrence of talk spurts (which would cause an increase in load on

the RT control channels). For example, it should be possible to reduce the hangover interval from 7 frames to a lower number such as 2 or 3. It is not yet known how this would impact control channel load or the occurrence of speech clipping.

Data Traffic Channel Design Principles

[0096] The data traffic channels are designed for full compatibility with the speech traffic channels, while reusing the MCS1 through MCS9 channel coding schemes defined for EGPRS.

Interleaving

[0097] For full-rate data channels, the interleaving is 0123/4567 block interleaving as defined in EGPRS. There is no need to deviate from EGPRS since the TBF has exclusive use of the channel until it is explicitly reassigned.

[0098] For half-rate data channels, the interleaving is 0246/1357 block interleaving, where each data block is interleaved over 4 consecutive odd or even bursts (alternate bursts).

Compatibility with Half-Duplex Mobiles

[0099] As in the half rate speech section, half-rate data traffic channels have the same advantages in statistical multiplexing efficiency as half-rate speech traffic channels.

Headers

[0100] Since the entire channel (either full-rate or half-rate) is dedicated to a TBF for the length of a data spurt, there is no need for additional header beyond what is in existing EGPRS. The USF is unused and could be redefined for other purposes. The TFI is similarly unused in this approach as defined, but has potential value for additional data multiplexing options if replaced with the ARI and/or TBFI, as defined in section 0.

Initial Burst of a Talk Spurt

[0101] As mentioned above, data channels may begin a data spurt on any assigned burst, offering the same improvement in delay to the beginning of the data spurt as for a talk spurt.

Traffic Channel Definition

[0102] The following traffic channels are defined.

[0103] Downlink Traffic Channel for Full Rate Speech (DTCH/FS). This channel comprises an entire time slot with eight burst chain interleaving. This channel uses GMSK modulation and unequal error protection.

[0104] Downlink Traffic Channel for Half Rate Speech (DTCH/HS). This channel comprises one half of a time slot on alternate bursts with four burst chain interleaving. Channel 1 on the time slot comprises even-numbered bursts, channel 2 comprises odd-numbered bursts. The modulation and coding schemes are to be specified.

[0105] Downlink Traffic Channel for Full Rate Data (DTCH/FD). This channel comprises an entire time slot with four burst block interleaving. EGPRS Phase I modulation and coding schemes (MCS1-MCS9) are used for the blocks. The USF is freed up.

[0106] Downlink Traffic Channel for Half Rate Data (DTCH/HD). This channel comprises one half of a time slot on alternate bursts with four burst block-interleaving. Channel 1 on the time slot comprises even-numbered bursts, channel 2 comprises odd-numbered bursts. EGPRS Phase I modulation and coding schemes (MCS1-MCS9) are used for the blocks (four alternate bursts). The USF is freed up.

[0107] Uplink Traffic Channel for Full Rate Speech (UTCH/FS). This channel comprises an entire time slot with eight burst chain interleaving. This channel uses GMSK modulation and unequal error protection.

[0108] Uplink Traffic Channel for Half Rate Speech (UTCH/HS). This channel comprises one half of a time slot on alternate bursts with four burst chain interleaving. Channel 1 on the time slot comprises even-numbered bursts, channel 2 comprises odd-numbered bursts. The modulation and coding schemes are to be specified.

[0109] Uplink Traffic Channel for Full Rate Data (UTCH/FD). This channel comprises an entire time slot with four burst block interleaving. EGPRS Phase I modulation and coding schemes (MCS1-MCS9) are used for the blocks.

[0110] Uplink Traffic Channel for Half Rate Data (UTCH/HD). This channel comprises one half of a time slot on alternate bursts with four burst block interleaving. Channel 1 on the time slot comprises even-numbered bursts, channel 2 comprises odd-numbered bursts. EGPRS Phase I modulation and coding schemes (MCS1-MCS9) are used for the

blocks (four alternate bursts).

Half-rate Traffic Channel Structure

[0111] Half-rate traffic channels comprise either even-numbered bursts (channel 0) or odd-numbered bursts (channel 1) of a time slot. This even or odd burst allocation of a half-rate traffic channel is not changed in a multiframe. It is worth noting that for current GSM traffic channels, the burst allocation alternates every 13 frames within a multiframe between odd bursts and even bursts. This change in burst allocation is necessary for maximum compatibility with half-duplex mobiles.

[0112] For data traffic channels, there is no MSACCH, and all allocated bursts in the time slot are available for traffic.

Multiplexing of Speech and Data Traffic

[0113] Two different half-rate traffic channels (speech or data) may be assigned to the two different phases, i.e. odd-numbered bursts or even-numbered bursts, of a time slot. The speech traffic channels (half-rate or full-rate) are allocated to a speech user for the duration of a talk spurt. A simplified fixed allocation procedure allocates an entire data traffic channel (either full-rate or half-rate) continuously to a TBF for the duration of a data spurt.

[0114] There is no multiplexing with full-rate speech users during a talk spurt, or with full-rate data users during a data spurt. After a full-rate talk or data spurt ends, the corresponding time slot is available for allocation to a full-rate or half-rate voice or data TBF.

Real Time Control Channel Design

[0115] New RT control channels provide the fast resource allocation needed to perform statistical multiplexing of voice and real-time data services. A burst-based contention access procedure allows a MS camped on the RT control channel to signal for uplink resource whenever an uplink traffic flow transitions from inactive to active (e.g. when the next talk spurt starts for a speech user). The mobile's Access Request Identifier, ARI, is transmitted in the access burst, which allows the network to immediately perform contention resolution. The network also includes the ARI in single-burst fast assignment messages in the downlink. Fast retry with 5 msec granularity increases the robustness of the single burst access and fast assignment scheme. Fast reassignment and termination provides the network the ability to allocate and reallocate resources and satisfy the QoS of RT TBFs.

Control Channel Functions

[0116] The existing BCCH or PBCCH provides the broadcast information needed for the mobile to access the GERAN. The existing CCCH or PCCCH provide the capability to negotiate the attributes of the initial TBF and to communicate the parameters needed for access to the RT control channels. Once in a voice, RT data or NRT data TBF, the following functions are needed (unless an exception is listed).

Access Request

[0117] The mobile must have the ability to request uplink resources on behalf of a TBF.

Traffic and Control Channel Assignment

[0118] The network must have the ability to make traffic and control channel assignments (for both uplink and downlink resources) to the mobile.

End-of-TBF Control

[0119] The mobile must have the ability to request the network to end a particular TBF. The network must have the ability to direct a mobile to immediately terminate a TBF.

Acknowledgment of Network Directives

[0120] The mobile must have the ability to acknowledge traffic and control channel assignments and end-of-TBF directives to trigger any necessary retry procedures to assure rapid resource allocation.

Timing Advance and Power Control

[0121] The network must be able to signal to the mobile any necessary adjustments in timing advance and power control.

Handover Signaling

[0122] If a mobile has an established TBF for voice or RT data, it is eligible for handover procedures. In this case, the mobile is required to provide periodic neighbor cell measurement reports to the network. The network will send the necessary handover directives to the mobile as appropriate to maintain the mobile under control of the RT control channels during and after handover to minimize service disruption.

Negotiation of Additional TBFs

[0123] It must be possible for either the mobile or network to begin negotiation of additional TBFs while under control of the RT control channels, subject to the multi-slot capabilities of the mobile. In particular, it must be possible to establish a default data TBF for control signaling while under control of the RT control channels.

AMR Signaling

[0124] During a voice TBF, it must be possible for the network to send periodic AMR mode commands to the mobile. During a voice TBF outside of a downlink talk spurt, it must be possible for the network to send periodic SID information to the mobile.

[0125] During a voice TBF, it must be possible for the mobile to send periodic AMR mode requests to the network. During a voice TBF outside of an uplink talk spurt, it must be possible for the mobile to send periodic SID information to the network.

RLC Signaling

[0126] RLC signaling may include, for example, ack/nack messages, and BEP measurements.

[0127] During a data TBF in the process of communicating in the downlink direction, it must be possible for the mobile to send periodic RLC control messages to the network.

[0128] During a data TBF in the process of communicating in the uplink direction, it must be possible for the network to send periodic RLC control messages to the mobile.

[0129] If a data traffic channel has already been allocated to a TBF in a direction requiring transmission of an RLC control message, existing RLC procedures already allow RLC control messages to be freely multiplexed with RLC data frames.

Control Channel Design Principles

[0130] The key functions of the RT control channels that enable statistical multiplexing are fast access, assignment, and acknowledgment. The following principles assure the rapid performance of these functions.

Burst-Based Channels

[0131] All fast access, assignment, and acknowledgment channels use single burst messages. This assures high capacity, point-to-point transmissions for compatibility with beam steering and power control procedures, and fine temporal granularity, with a transmission opportunity every 5 msec.

Access Request Identifier

[0132] Each mobile is assigned an ARI as a unique identifier during access and assignment procedures on the RT control channels. By including the ARI in the access burst, the network performs contention resolution immediately rather than waiting for contention resolution procedures on a traffic channel, as in GPRS and EGPRS. The network may respond immediately with a single burst assignment message including the ARI.

Half-Rate and Full-Rate Channels

[0133] The fast access, assignment, and acknowledgment channels are typically allocated a full-rate channel with all the bursts in a given slot. As an alternative, these channels may also be allocated as half-rate channels using either all odd or all even bursts in a slot.

[0134] Note in particular that a fast access channel is completely allocated for contention access. The network does not broadcast USF to signal contention opportunities. Since there is no need to monitor USF, this saves up to 40 msec in waiting to perform an access attempt in certain situations.

Fast Retry

[0135] Since all full-rate access, assignment, and acknowledgment channels have 5 msec granularity, this allows for rapid retry of these procedures up to once every 5 msec. Half-rate channels have a 10 msec granularity. Even with a high error rate on these channels, access and assignment procedures can be performed quickly and efficiently. Note that frequency hopping is desirable on these channels to reduce or eliminate burst-to-burst fading correlation.

Fast Control Channel Assignment

[0136] The fast access, assignment, and acknowledgment channels are allocated at the establishment of a TBF, and continue to be used throughout the TBF unless they are reassigned.

Associated Control Channel Definitions

[0137] Several new associated control channels are defined to support the necessary control channel functions while the mobile is active on a traffic channel in the direction that control signaling is required.

Fast Associated Control Channel (FACCH)

[0138] A FACCH is associated with each traffic channel defined in 0. Thus the FACCH associated with the DTCH/FS is referred to as FACCH/DFS, for FACCH on a downlink full-rate speech channel. Other FACCH channels are named consistently. Standard FACCH coding as in GSM AMR bearer is used.

Dim-and-burst FACCH (DFACCH)

[0139] A DFACCH is associated with each traffic channel defined in 0. Thus the DFACCH associated with the UTCH/FS is referred to as DFACCH/UFS. Other DFACCH channels are named consistently.

[0140] DFACCH coding is for further study beyond the present invention.

Burst-Based FACCH (BFACCH)

[0141] A BFACCH is associated with each traffic channel defined in 0. Thus the BFACCH associated with the DTCH/FS is referred to as BFACCH/DFS. Other BFACCH channels are named consistently.

[0142] Burst based control messages are transmitted over BFACCH replacing single burst speech or data for fast access, assignment and acknowledgment while on a traffic channel. BFACCH is distinguished from speech or data traffic using a new training sequence or stealing bits. BFACCH channel coding is for further study.

Modified Slow Associated Control Channel (MSACCH)

[0143] A MSACCH is associated with each traffic channel defined in 0. Thus the MSACCH associated with the DTCH/FS is referred to as MSACCH/DFS. Other MSACCH channels are named consistently.

[0144] A MSACCH is a set of reserved bursts on a periodical basis and has the same structure as SACCH defined for GSM speech traffic channels.

[0145] Block based signaling messages, e.g. Neighbor Measurement Report, are transmitted over MSACCH.

Common Uplink Control Channel Definition

Fast Random Access Channel (FRACH)

[0146] A FRACH is designed to transmit single burst fast contention access messages. The traffic on the FRACH is isolated from the RACH and PRACH. Since the mobiles accessing on the FRACH are assumed to be time-aligned, the guard period on the FRACH burst is shorter and the message size can be larger. The maximum message length on the FRACH is TBD.

[0147] A FRACH comprises either a full time slot on all bursts (full-rate), or a half time slot on alternate bursts (half-rate).

Fast Acknowledgment Channel (FACKCH)

[0148] A FACKCH is designed to transmit single burst messages to acknowledge assignments and termination directives from the network. FACKCH transmissions occur in reserved bursts.

[0149] Single burst acknowledgment message is transmitted on FACKCH on a polled basis using a RRBP scheme. This permits multiple burst-based assignment/acknowledgment sequences to be completed within a 20-msec block period and improves the speed and reliability of real-time statistical multiplexing.

[0150] A FACKCH comprises either a full time slot on all bursts (full-rate), or a half time slot on alternate bursts (half-rate).

Uplink Periodic Reservation Channel (UPRCH)

[0151] An UPRCH is used to transmit signaling messages that need to be updated on a periodic basis, e.g. SID_Update and Neighbor Measurement Report. It is possible that a traffic channel is relinquished (e.g. when a talk spurt ends) before a signaling message (e.g. spans 480 ms) is transmitted completely on the MSACCH. An UPRCH is designed for MSACCH signaling continuity when an uplink traffic channel is released.

[0152] An UPRCH is released at the assignment of an uplink traffic channel, and is reassigned each time at the release of an uplink traffic channel.

[0153] A UPRCH comprises either a full time slot on all bursts (full-rate), or a half time slot on alternate bursts (half-rate). The network reserves one of every 26 bursts on a full-rate UPRCH for each voice TBF not in an uplink talk spurt. 26 voice TBFs can simultaneously share a full-rate UPRCH.

Uplink Block Message Channel (UBMCH)

[0154] An UBMCH is designed for block (4 bursts) messages, e.g. RLC signaling, using polled reservation bursts in a RRBP-like scheme.

Common Downlink Control Channel Definition

Fast Assignment Channel (FASSCH)

[0155] A FASSCH is designed to transmit single burst assignment and termination messages when there is no downlink traffic allocated to the MS. Different messages are used to assign downlink traffic channels, downlink control channels, uplink traffic channels, and uplink control channels.

[0156] A FASSCH comprises either a full time slot on all bursts (full-rate), or a half time slot on alternate bursts (half-rate).

Downlink Periodic Reservation Channel (DPRCH)

[0157] A DPRCH is used to transmit signaling messages that need to be updated on a periodic basis, e.g. SID_Update, timing advance, and power control. It is possible that a traffic channel is relinquished (e.g. when a talk spurt ends) before a signaling message (e.g. spans 480 ms) is transmitted completely on the MSACCH. A DPRCH is designed for MSACCH signaling continuity when a downlink traffic channel is released.

[0158] A DPRCH is released when the downlink traffic channel is assigned, and reassigned each time at the release of the downlink traffic channel.

[0159] A DPRCH comprises either a full time slot on all bursts (full-rate), or a half time slot on alternate bursts (half-rate). The network reserves one of every 26 bursts on a full-rate DPRCH for each voice TBF not in a downlink talk

spurt. 26 voice TBFs can simultaneously share a full-rate DPRCH.

Downlink Block Message Channel (DBMCH)

[0160] A DBMCH is designed for block (4 bursts) messages, e.g. RLC signaling, handover directives, etc.

Multiplexing of Common Control Channel

[0161] The FRACH, FACKCH, UPRCH, FASSCH, and DPRCH may be either full-rate or half-rate control channels. A full-rate control channel uses all bursts in each multiframe. A half-rate control channels uses either every odd or every even burst in each multiframe.

[0162] These channels are not multiplexed on the same full-rate or half-rate channel.

[0163] Two different half-rate control or traffic channels may be assigned to the two different phases (all odd or all even) of a slot. Note that the burst allocation for half-rate control channels is compatible with and identical to the burst allocation for half-rate traffic channels.

[0164] The multiplexing of DBMCH and UBMCH with other common control channel is FFS.

Overview of Real Time TBF Operation

[0165] The definition of TBF (GPRS Phase 1) is enhanced to support RT services. Each RT TBF may be bi-directional (e.g. speech) or unidirectional (e.g. best effort data). The initial establishment of a RT TBF is carried on a PCCCH or CCCH. Each RT TBF has an associated TBF profile. The negotiation of a RT TBF profile during TBF setup includes the QoS requirements and the protocol stack supported by the RAB.

[0166] Additional information that is exchanged during initial TBF setup includes the following:

[0167] A temporary MS Access Request Identifier, ARI, is allocated by the network and is sent to the MS.

[0168] Carrier information (including frequency-hopping sequence) is communicated to the MS, either by broadcast message over PBCCH/BCCH or explicit signaling. The details are FFS.

[0169] TBF identifier (TBFI) is assigned to the MS per requested TBF.

[0170] TBF Inactivity Timer is negotiated for RT and NRT data TBFs. It is optional for RT speech TBF (FFS).

[0171] Once a RT TBF is established, the MS is assigned a set of RT control channels, namely FRACH, FACKCH, UBMCH and UPRCH for uplink signaling, and FASSCH, DBMCH and DPRCH for downlink signaling and control. An UPRCH (or a DPRCH) may be reassigned each time an UTCH (or a DTCH) is released. The rest of the control channels, i.e. FRACH, FACKCH and UBMCH for uplink, and FASSCH and DBMCH for downlink, do not need to be reassigned for the duration of the TBF.

[0172] The uplink and/or downlink traffic associated with the RT TBF is activated independently using fast access and fast assignment procedures. Additional RT and NRT TBF(s) can be negotiated and established on the RT control channel(s).

[0173] An established bi-directional TBF has the following 4 states: TBF Inactive, DL Active, UL Active, and DL and UL Active. The state transition diagram for a single bi-directional RT TBF is shown in FIG. 6. The state transitions for a unidirectional RT TBF and NRT TBF (as defined in EGPRS Phase 1) are a subset of the states and allowable transitions associated with bi-directional RT TBF.

RT TBF State Definition

[0174] An established bi-directional RT TBF has four states, as shown in FIG. 6. Channel allocation is also shown in FIG. 5 (Table 1).

RT TBF State: DL Inactive

[0175] In this state, there is no uplink or downlink traffic channel assigned to the MS for the TBF. The MS and the network may independently initiate uplink and downlink traffic, set up a new TBF, end a current TBF, or end all TBFs associated with the MS. The network may also reassign common control channels to the MS.

[0176] A timer may be associated with this state per RT TBF, which allows the MS to be in TBF established state for a configurable time after the downlink and uplink traffic end. This avoids renegotiation of the RT TBF profile, should downlink or uplink traffic flow resume within a short period of time.

RT TBF State: DL Active

[0177] In this state, the MS is assigned a downlink traffic channel associated with the RT TBF. Downlink single burst messages are transmitted using BFACCH. Other downlink signaling and control messages are transmitted using FACCH and/or MSACCH.

[0178] Uplink signaling and control messages are carried on uplink common channels assigned to the MS, which are shared among parallel TBFs the MS may have established.

[0179] New TBFs may be initiated on the RT control channels.

RT TBF State: UL Active

[0180] In this state, the MS is assigned an uplink traffic channel associated with the RT TBF.

[0181] Uplink single burst messages are transmitted using BFACCH. Other uplink signaling and control messages are transmitted using FACCH and/or MSACCH.

[0182] Downlink signaling and control messages are carried on downlink common control channels assigned to the MS, which are shared among parallel TBFs the MS may have established.

[0183] New TBFs may be initiated on the RT control channels.

RT TBF State: DL and UL Active

[0184] In this state, the MS is assigned an uplink traffic channel and a downlink traffic channel associated with the RT TBF.

[0185] Both downlink and uplink single burst messages are transmitted using BFACCH. Other signaling and control messages are transmitted using FACCH and/or MSACCH.

[0186] New TBFs may be initiated on the RT control channels.

Procedures Associated with Single RT TBF State Transition

[0187] A set of procedures is defined to perform the state transitions associated with an RT TBF. FIG. 6 (table 2) shows the procedures associated with each single RT TBF state transition and the applicable states involved. The definitions and message flows for the procedures are further described below.

Control Messages

Uplink Signaling and Control Messages

[0188] FIG. 7 (table 3) provides a summary of the uplink signaling and control messages and the control channels used.

Access Request

[0189] This single burst message is sent over BFACCH if an UTCH is allocated; otherwise it is sent over FRACH. Its usage and contents are further described in Section 0.

Acknowledge to Assignment

[0190] This set of single burst messages is sent over BFACCH if an UTCH is allocated; otherwise they are sent over FACKCH. Their usage and contents are further described later in the section devoted to that issue.

AMR Mode Request

[0191] AMR Mode Request (2 bits) is sent in-band if an UTCH is allocated. Otherwise, it is sent over UPRCH, multiplexed with other periodic signaling messages, e.g. SID Update and Neighbor Measurement Report. The details of the multiplexing of these messages are FFS.

SID Update

[0192] Sid Update is sent over UPRCH, multiplexed with AMR Mode Request and Neighbor Measure Report.

Neighbor Measurement Report

[0193] It is sent over MSACCH if a UTCH is allocated; otherwise, it is sent over UPRCH, multiplexed with other periodic signaling messages, e.g. SID Update and AMR Mode Request.

RLC Signaling

[0194] RLC signaling is sent over a UTCH or UBMCH, according to EGPRS Phase 1 RLC procedures.

End TBF Request

[0195] This single burst message is sent on BFACCH or FRACH. Its usage and contents are further described below.

Downlink Signaling and Control Messages

[0196] FIG. 8 (table 4) provides a summary of the downlink signaling and control messages, and the RT control channels used.

Assignment

[0197] All Assignment messages are burst based. They are sent over BFACCH if a DTCH is allocated; otherwise they are sent over FASSCH. Their usage and contents are further described below.

AMR Mode Command

[0198] AMR Mode Command (2 bits) is sent inband if a DTCH is allocated. Otherwise, it is sent over DPRCH, multiplexed with other periodic signaling messages, e.g. SID Update and Timing Advance. The details of the multiplexing of these messages are FFS.

SID Update

[0199] SID_Update is sent over DPRCH, multiplexed with AMR Mode Command and Timing Advance.

Handover Directives

[0200] Handover Directives are sent over FACCH if a DTCH is allocated; otherwise they are sent over DBMCH.

RLC Signaling

[0201] RLC signaling is sent over a DTCH or DBMCH, according to EGPRS Phase 1 RLC procedures.

Timing Advance

[0202] Timing Advance is sent over MSACCH if a DTCH is allocated to the MS; otherwise it is sent over DPRCH.

Power Control

[0203] Power Control is sent over MSACCH if a DTCH is allocated to the MS; otherwise it is sent over DPRCH.

End TBF Command

[0204] This single burst message is sent on BFACCH or FASSCH by the network to terminate a single TBF or all TBFs established by the MS. Its contents are further described below.

Downlink Burst Message Contents

[0205] FIG. 9 (table 5) provides a summary of downlink burst messages and their content.

Assign UTCH

[0206] This message is used to allocate an UTCH per specified TBF (identified by TBFI). The ARI field is included for fast contention resolution.

Deferred Assign UTCH

[0207] This message is used to delay assignment of UTCH for the specified TBF (identified by TBFI). The delay field indicates the period for which the mobile must wait for an assignment of uplink resource before it may try again.

Assign DTCH

[0208] This message is used to allocate a DTCH per specified TBF (identified by TBFI). RRBP field is used to indicate the reserved burst for sending the acknowledgment.

Assign UPRCH

[0209] This message is used to allocate an UPRCH to an MS for uplink periodic signaling when there is no UTCH assigned to the MS. The UPRCH is reassigned when an UTCH is released and the periodic uplink signaling on the MSACCH needs to continue on the UPRCH.

Assign DPRCH

[0210] This message is used to allocate a DPRCH to an MS for downlink periodic signaling when there is no DTCH assigned to the MS. The DPRCH is reassigned when a DTCH is released and the periodic downlink signaling on the MSACCH needs to continue on the DPRCH.

Assign FRACH

[0211] This message is used to allocate an uplink FRACH to an MS for fast contention access. A FRACH is assigned to an MS at the initial TBF setup and is usually not changed for the duration of the established TBF.

Assign FACKCH

[0212] This message is used to allocate an uplink FACKCH to an MS for sending acknowledgment on reserved bursts when polled. A FACKCH is assigned to an MS at the initial TBF setup and is usually not changed for the duration of the established TBF.

Assign FASSCH

[0213] This message is used to allocate a downlink FASSCH to an MS for monitoring assignment messages. A FASSCH is assigned to an MS at the initial TBF setup and is usually not changed for the duration of the established TBF.

End TBF Command

[0214] This message is used by the network to terminate one TBF (identified by TBFI) or all TBFs (TBFI = 0) established by a MS.

Uplink Burst Message Contents

[0215] FIG. 10 (table 6) provides a summary of uplink burst messages and their contents.

Access Request

[0216] This message is used by an MS to request for UTCH per specified TBF (identified by TBFI).

Acknowledge UTCH/DTCH/UPRCH/DPRCH/FRACH/FACKCH/FASSCH

[0217] The MS uses this set of messages to acknowledge traffic and control channel assignments.

Acknowledge End TBF

[0218] The MS uses this message to acknowledge an End TBF Command.

End TBF Request

[0219] The MS uses this message to request for termination of a TBF or all TBFs (TBFI = 0) established by the MS.

Information Element Definition

[0220]

IE	Name	Length (bits)	Description
ARI	Access Request Identifier	9	Uniquely identifiers each MS on RT control channel
DMT	Downlink Message Type	4	Identifies downlink burst message type
UMT	Uplink Message Type	4	Identifies uplink burst message type
TBFI	TBF Identifier	2	Identifies 1 of 3 possible TBFs in use by a MS; 0 identifies all TBFs for a MS
RRBP	Relative Reserved Burst Period	2	Offset to reserved uplink burst for acknowledgment of assignment
CID	Carrier Identifier	4	Identifies up to 16 carriers in current cell; Carrier descriptions provided on PBCCH or PCCCH
CTS	Carrier Time Slot	3	Time slot number on assigned carrier.
PH	Phase	2	Indicates full-rate or half-rate, and odd bursts or even bursts
SD	Start Delay	1	Indicates whether to start on 1st or 2nd eligible burst of a radio block
OFF	Offset	5	Frame number in each 26-multiframe for periodic allocation
delay	Delay	6	The number of 40 msec intervals a mobile must wait before it may again try to request an uplink traffic channel
reason	Reason Code	2	Further status for End TBF command/request

[0221] The methods described above has been applied to a system for access and assignment to real-time and non-real-time services in GERAN as follows. The following four subsections describe the four key procedures needed to perform real-time scheduling of uplink and downlink traffic channel resources (UTCH and DTCH, respectively) in a system that statistically multiplexes voice, real-time data, and non-real-time data. Each flow of data is called a TBF (temporary block flow). Access requests occur on a fast random access channel (FRACH). Traffic channel assignments occur on either a common fast assignment channel (FASSCH) if the mobile is not on a downlink traffic channel, or on a burst-based fast associated control channel (BFACCH) that steals a single burst from ongoing downlink traffic. One of the four bursts of a traffic channel block is blanked and replaced with a burst-based control message. Acknowledgments to assignments occur on either a common fast acknowledgment channel (FACKCH) if the mobile is not on an uplink traffic channel, or on a BFACCH. At the end of an uplink (downlink) talk spurt or data spurt, the network reallocates an uplink (downlink) periodic reservation channel [UPRCH (DPRCH)] to allow continuity of slow associated control signaling between the mobile and the network.

Start Uplink Traffic (SUT)

[0222] As shown in FIG. 11, a mobile station (MS) uses the SUT procedure to start an uplink traffic flow associated with a TBF. The uplink traffic flow is directed to a base station which is part of a network using GERAN methods.

End Uplink Traffic (EUT)

[0223] As shown in FIG. 12, the network and the MS use the EUT procedure to terminate an uplink traffic flow associated with a TBF.

Start Downlink Traffic (SDT)

[0224] As shown in FIG. 13, the network uses the SDT procedure to start a downlink traffic flow associated with a TBF.

End Downlink Tragic (EDT)

[0225] As shown in FIG. 14, the network uses the EDT procedure to terminate a downlink traffic flow associated with a TBF.

Reassign Uplink Traffic (RUT)

[0226] As shown in FIG. 15, the network uses the RUT procedure to assign a new uplink traffic channel to the MS associated with a TBF.

Reassign Downlink Traffic (RDT)

[0227] As shown in FIG. 16, the network uses the RDT procedure to assign a new downlink traffic channel to the MS associated with a TBF.

Reassign Uplink Control (RUC)

[0228] As shown in FIG. 17, the network uses the RUC procedure to assign a new uplink control channel to the MS.

Reassign Downlink Control (RDC)

[0229] As shown in FIG. 18, the network uses the RDC procedure to assign a new downlink control channel to the MS.

End TBF(ET)

[0230] As shown in FIG. 19, the ET procedure is used to terminate a TBF or all TBFs. The End TBF procedure may also be used in Error cases for all other scenarios. Whenever error occurs during Assignment, either the MS or the network may abort the on-going procedure using End TBF messages.

Performance results

For Interleaving for Half Rate Channels in EGPRS Phase II

[0231] Half-rate traffic channels comprise either even-numbered bursts (channel 0) or odd-numbered bursts (channel 1). The known GSM half rate channels are shown in FIG. 20 . It is worth noting that the bursts allocation changes every 13 frames within a multiframe in GSM defined half-rate speech channels. Hence channel 1 is assigned bursts 2j, j=0,1,2,3,4,5,6 in multiframe 0. In multiframe 1, channel 1 consists of bursts 2j+1, j=6,7,8,9,10,11. Therefore, a mobile assigned to channel one has to receive on even bursts in one multi-frame and odd-bursts in the next multiframe. This switching between even and odd bursts is not well suited for dynamic assignment of uplink and downlink channels.

[0232] FIG. 21 shows a half-rate traffic channel structure according to the present invention. Here even-numbered bursts or odd-numbered bursts allocation is not changed for the duration of the assignment. Note that, unlike in the known GSM half rate traffic channel structure, here a mobile station on channel 1 always reads only the even bursts, for traffic as well as for MSACCH, i.e., bursts 2j, j=0,1,2,.... The MSACCH is also on even bursts 2j, j=6,19,.32,... This small change from the GSM half rate channel is critical for flexibility with half duplex operation on dynamically assigned

time slots.

[0233] Also, half-rate control channels are defined with the same structure, that is, on all even or all odd numbered frames.

Half Duplex Operation

[0234] Higher efficiency can be achieved through statistical multiplexing when a large pool of resources is available for assignment. However, half duplex (i.e., Type I) mobile stations constrain the channels that can be assigned in the uplink and downlink directions. This impacts the resources available for assignment of traffic and control channels. The resource constraints imposed by a half duplex mobile station may differ depending on its functions during different periods of activity. The periods of activity to be considered are as follows:

[0235] No traffic in either direction - assignment of uplink control channels is constrained by downlink control channels and vice versa

[0236] Traffic in the downlink only - assignment of downlink traffic channel is constrained by uplink control channels and vice versa

[0237] Traffic in the uplink only - assignment of uplink traffic channel is constrained by downlink control channels and vice versa

[0238] Traffic in both directions - assignment of uplink traffic channel is constrained by downlink traffic channel and vice versa

[0239] As an illustrative example, consider the case where an uplink talkspurt is in progress, and a downlink talkspurt is just starting. Figure 22 shows the half rate channels to which a downlink talkspurt for a Class 1 mobile station can be allocated when 0246/1357 interleaving is assumed. If the mobile is assumed to be active during odd (1357) bursts on uplink time slot 5 (which overlaps with downlink time slot 0), then on the downlink it can be allocated even bursts on time slots 3 through 7 and odd bursts on time slots 0 through 4. Therefore, it can be assigned to 10 of 16 possible half rate channels on the downlink. If consecutive burst (0123/4567) interleaving is assumed, the mobile station can only be assigned to 7 out of 16 possible half rate channels on the downlink (see Figure 23). Figures 24 and 25 illustrate the corresponding resource availability for a Class 8 mobile station. In both cases, for these classes of mobile stations that the resource pool available for assignment of traffic channels is 43% larger with 0246/1357 interleaving than with 0123/4567 interleaving can be observed.

[0240] FIG 22 shows a resource pool to which a downlink talkspurt for a Class 1 (half duplex, single slot capable, $T_{ta} = 3$, $T_{rb} = 2$, $T_{tb} = T_{ra} = 0$) MS may be allocated; 4 burst interleaving is assumed where interleaving is carried out over alternate (odd/even) bursts.

[0241] FIG. 23 shows a resource pool to which a downlink talkspurt for a Class 1 (half duplex, single slot capable, $T_{ta} = 3$, $T_{rb} = 2$, $T_{tb} = T_{ra} = 0$) MS may be allocated; 4 burst interleaving is assumed where interleaving is carried out over consecutive bursts.

[0242] FIG. 24 shows a resource pool to which downlink transmissions for a Class 8 (half duplex, downlink 4-slot capable, $T_{ta} = 4$, $T_{rb} = 1$, $T_{tb} = T_{ra} = 0$) MS may be allocated; 4 burst interleaving is assumed where interleaving is carried out over alternate bursts.

[0243] FIG. 25 shows a resource pool to which downlink transmissions for a Class 8 (half duplex, downlink 4-slot capable, $T_{ta} = 4$, $T_{rb} = 1$, $T_{tb} = T_{ra} = 0$) MS may be allocated; 4 burst interleaving is assumed where interleaving is carried out over consecutive bursts.

[0244] FIG. 26 shows bursts on which a downlink talkspurt may start for a Class 1 (half duplex, single slot capable, $T_{ta} = 3$, $T_{rb} = 2$, $T_{tb} = T_{ra} = 0$) MS; alternate burst interleaving is assumed.

[0245] FIG. 27 shows bursts on which a downlink talkspurt may start for a Class 1 (half duplex, single slot capable, $T_{ta} = 3$, $T_{rb} = 2$, $T_{tb} = T_{ra} = 0$) MS; consecutive burst interleaving is assumed.

Delay in Starting Talkspurt (Half Rate)

[0246] Again, consider the case of the mobile that is active during odd (1357) bursts on uplink time slot 5 (which overlaps with downlink time slot 0). Then on the downlink it can be allocated even bursts on time slots 3 through 7 and odd bursts on time slots 0 through 4. FIG. 26 shows the bursts during which a downlink talkspurt may start for a Class 1 mobile station when 0246/1357 interleaving is used. FIG. 26 also shows the bursts during which a downlink talkspurt may start when 0123/4567 interleaving is used.

[0247] Given an *available* half rate channel on the downlink, that can be assigned to the Class 1 mobile (under the duplex constraints), the following can be observed:

Granularity in start time for transmission (see Figures 26 and 27) is 40 ms for 0123/4567 interleaving and 10 ms for 0246/1357 interleaving if it is assumed that the interleaving sequence can start on any burst; and

Average delay to start (see Figures 26 and 27) is 20 ms for 0123/4567 interleaving and 5 ms for 0246/1357 inter-

leaving.

Performance of Interleaving for Half Rate Channels

[0248] The performance of the two different interleaving schemes for half rate channels discussed above is summarized in the table of FIG. 28. With ideal frequency hopping, the performance of the 0246/1357 interleaver is slightly worse than the 0123/4567 interleaver. However, with no frequency hopping, the 0246/1357 interleaver exhibits a gain of 1.0 dB over the 0123/4567 interleaver for a slow fading typical urban channel. The 0246/1357 interleaver exhibits a modest gain of 0.4 to 0.8 dB even in a fast fading channel..

[0249] FIG. 29 is a table showing performance of the two interleaving methods with QPSK modulation.

For Interleaving for Full Rate Channels in EGPRS Phase II

[0250] FIG. 30 shows the resource pool to which a Full Rate downlink talkspurt for a Class 1 (half duplex, single slot capable, $T_{ta} = 3$, $T_{rb} = 2$, $T_{tb} = T_{ra} = 0$) MS may be allocated. A Full Rate channel occupies an entire slot (both even and odd bursts).

[0251] FIG. 31 shows the resource pool to which a Full Rate downlink talkspurt for a Class 1 (half duplex, single slot capable, $T_{ta} = 3$, $T_{rb} = 2$, $T_{tb} = T_{ra} = 0$) MS may be allocated; 4 burst interleaving is assumed where interleaving is carried out over alternate (odd/even) bursts. A Full Rate channel in FIG. 31 is defined as the aggregation of two half rate channels on consecutive bursts.

[0252] In presently known GSM, Full Rate channels occupy an entire timeslot as shown in FIG 30. For a Class 1 mobile with a talkspurt active on uplink time slot 5, a starting downlink talkspurt can be assigned only on downlink timeslot 3 or 4, which is 2 of 8 (25%) downlink timeslots on each carrier. This does not efficiently use the system resource pool and bandwidth.

[0253] According to one embodiment of the present invention, a new method and system to improve the number of available resources for Full Rate channels is set forth. The new method and system for Full Rate channels use an interleaving scheme described previously for half rate channels. In order to maximize the number of resources on which the starting downlink talkspurt can be assigned, the Full Rate channel for EGPRS Phase 2 is re-defined. The Full Rate channel in EGPRS Phase 2 is re-defined as two half rate channels on consecutive timeslots. FIG. 31 shows an example in which the Full Rate uplink talkspurt is acitve on the odd bursts of uplink time slots 5 and 6. The re-definition now allows the downlink talkspurt to be assigned to the following downlink timeslot pairs: the even bursts of timeslot pairs (4,5), (5,6), (6,7), even bursts of time slot 7 and odd bursts of time slot 0, and the odd bursts of time slots (0,1), (1,2), (2,3), (3,4).

[0254] Thus a total of eight of the sixteen (50%) possible timeslot pairs can be assigned while still satisfying the half duplex constraint of the Class 1 mobile. The Full Rate Channel method and system according to the present invention offer significant advantages in statistical multiplexing of Full Rate channels over the statistical multiplexing of the previously known interleaving scheme for Full Rate channels.

Delay in Starting Talkspurt (Full Rate)

[0255] For the new, re-defined full rate channel, given an *available* full rate channel on the downlink, that can be assigned to the Class 1 mobile (under the duplex constraints), the following can be observed:

Granularity in start time for transmission: (see FIGs. 30 and 31) 10 ms for 0246/1357 interleaving if it is assumed that the interleaving sequence can start on any burst; and

Average delay to start:(see FIGs. 30 and 31) 5 ms for 0246/1357 interleaving.

[0256] In summary, the alternate (0246/1357) burst interleaving for half rate channels offers the following advantages: larger resource pools for statistical multiplexing under half duplex constraints imposed by mobile station class; lower delay to the start of a talkspurt; and better link level performance when there is no frequency hopping or when frequency hopping is non-ideal.

[0257] The ability to multiplex voice and data and the play out delays for speech are equivalent for both interleaving approaches. Therefore, it is concluded that 0246/1357 offers significant advantages without any penalties, and 0246/1357 burst interleaving is the preferred approach for EGPRS Phase II half rate channels.

[0258] Additionally, because of the re-definition of a full rate channel as two consecutive half rate channels, it is concluded that the full rate channel according to the present invention likewise offers the advantage of larger resource pools for statistical multiplexing under half duplex constraints.

[0259] Thus, it will now be understood that there has been disclosed a new, advantageous system and method for multiplexing and interleaving full rate channels which use two consecutive half rate channels. While the invention has been particularly illustrated and described with reference to preferred embodiments thereof, it will be understood by

those skilled in the art that changes in form, details and applications may be made therein.

Claims

1. A system for communicating using wireless time division multiplexed communications in which time is divided into a plurality of frames and each frame is divided into *N* data bursts, said system comprising:

   means for defining a half rate channel as a series of bursts that occur periodically every N bursts once per frame;
   means for defining a full rate channel as two consecutive half rate channels; and
   means for transmitting said full rate channel from a first station to a second station.

2. The system of claim 1, wherein 0246/1357 interleaving is used for said full rate channel.

3. The system of claim 1, wherein 0246/1357 interleaving is used with non-ideal frequency hopping transmitting of said full rate channel because of the improved link performance provided thereby.

4. The system of claim 1, wherein 0246/1357 interleaving is used because of a lower delay to the start of a talkspurt of said half rate channels and hence said full rate channel than 0123/4567 interleaving.

5. The system of claim 1, wherein 0246/1357 interleaving is used because of larger resource pools for statistical multiplexing under half duplex constraints imposed by mobile stations provided for said full rate channel relative to 0123/4567 interleaving.

6. A system for communicating using wireless time division multiplexed communications in which time is divided into a plurality of frames and each frame is divided into *N* data bursts, said system comprising:

   a first multiplexer defining a half rate channel as a series of bursts that occur periodically every N bursts once per frame;
   a second multiplexer defining a full rate channel as two consecutive half rate channels; and
   a transmitter transmitting said full rate channel from a first station to a second station.

7. The system of claim 6, wherein 0246/1357 interleaving is used for said full rate channel.

8. The system of claim 6, wherein 0246/1357 interleaving is used with non-ideal frequency hopping transmitting of said full rate channel because of the improved link performance provided thereby.

9. The system of claim 6, wherein 0246/1357 interleaving is used because of a lower delay to the start of a talkspurt of said half rate channels and hence said full rate channel than 0123/4567 interleaving.

10. The system of claim 6, wherein 0246/1357 interleaving is used because of larger resource pools for statistical multiplexing under half duplex constraints imposed by mobile stations provided for said full rate channel relative to 0123/4567 interleaving.

11. A method for communicating using wireless time division multiplexed communications in which time is divided into a plurality of frames and each frame is divided into N data bursts, said method comprising the steps of:

    interleaving bursts using a 0246/1357 sequence to provide a plurality of half rate channels;
    using two half rate channels on consecutive timeslots of said plurality of half rate channels to provide a full rate channel; and
    transmitting said full rate channel bursts from a first station to a second station.

12. A method as set forth in claim 11 wherein said transmitting said full rate channel from a first station to a second station step further includes using non-ideal frequency hopping during the transmitting.

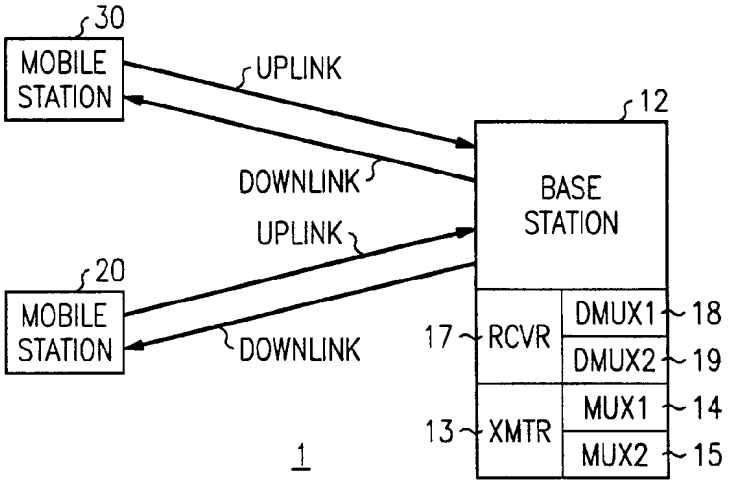
30
MOBILE STATION
UPLINK
DOWNLINK
12
BASE STATION
UPLINK
20
MOBILE STATION
DOWNLINK
17
RCVR
DMUX1
18
DMUX2
19
13
XMTR
MUX1
14
MUX2
15
1

FIG. 1

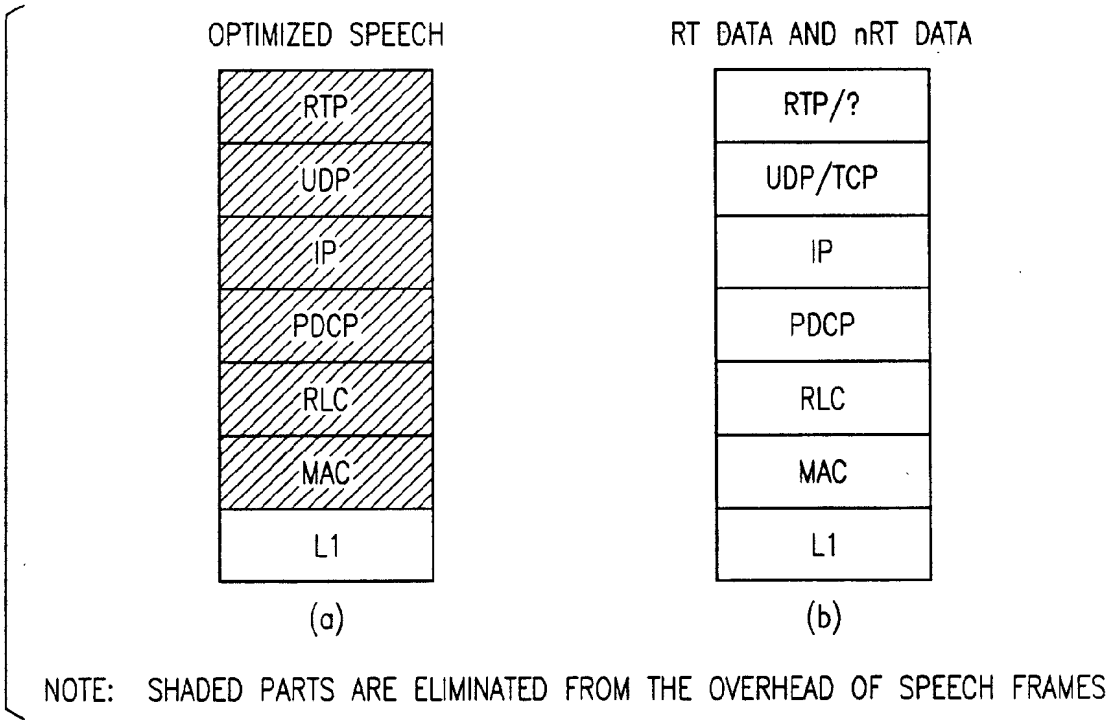
OPTIMIZED SPEECH
RTP
UDP
IP
PDCP
RLC
MAC
L1
(a)
RT DATA AND nRT DATA
RTP/?
UDP/TCP
IP
PDCP
RLC
MAC
L1
(b)
NOTE: SHADED PARTS ARE ELIMINATED FROM THE OVERHEAD OF SPEECH FRAMES

FIG. 2

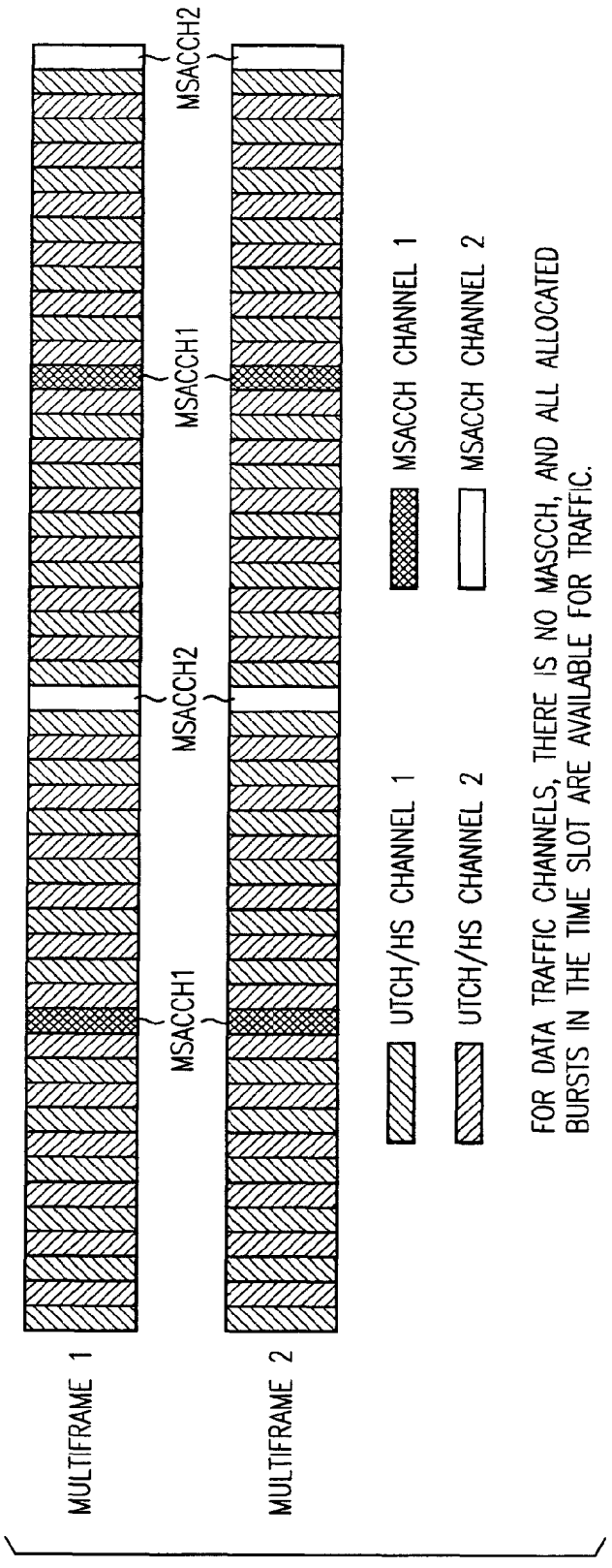
MULTIFRAME 1
MULTIFRAME 2
MSACCH1
MSACCH2
MSACCH1
MSACCH2
UTCH/HS CHANNEL 1
UTCH/HS CHANNEL 2
MSACCH CHANNEL 1
MSACCH CHANNEL 2
FOR DATA TRAFFIC CHANNELS, THERE IS NO MASCCH, AND ALL ALLOCATED BURSTS IN THE TIME SLOT ARE AVAILABLE FOR TRAFFIC.

FIG. 3

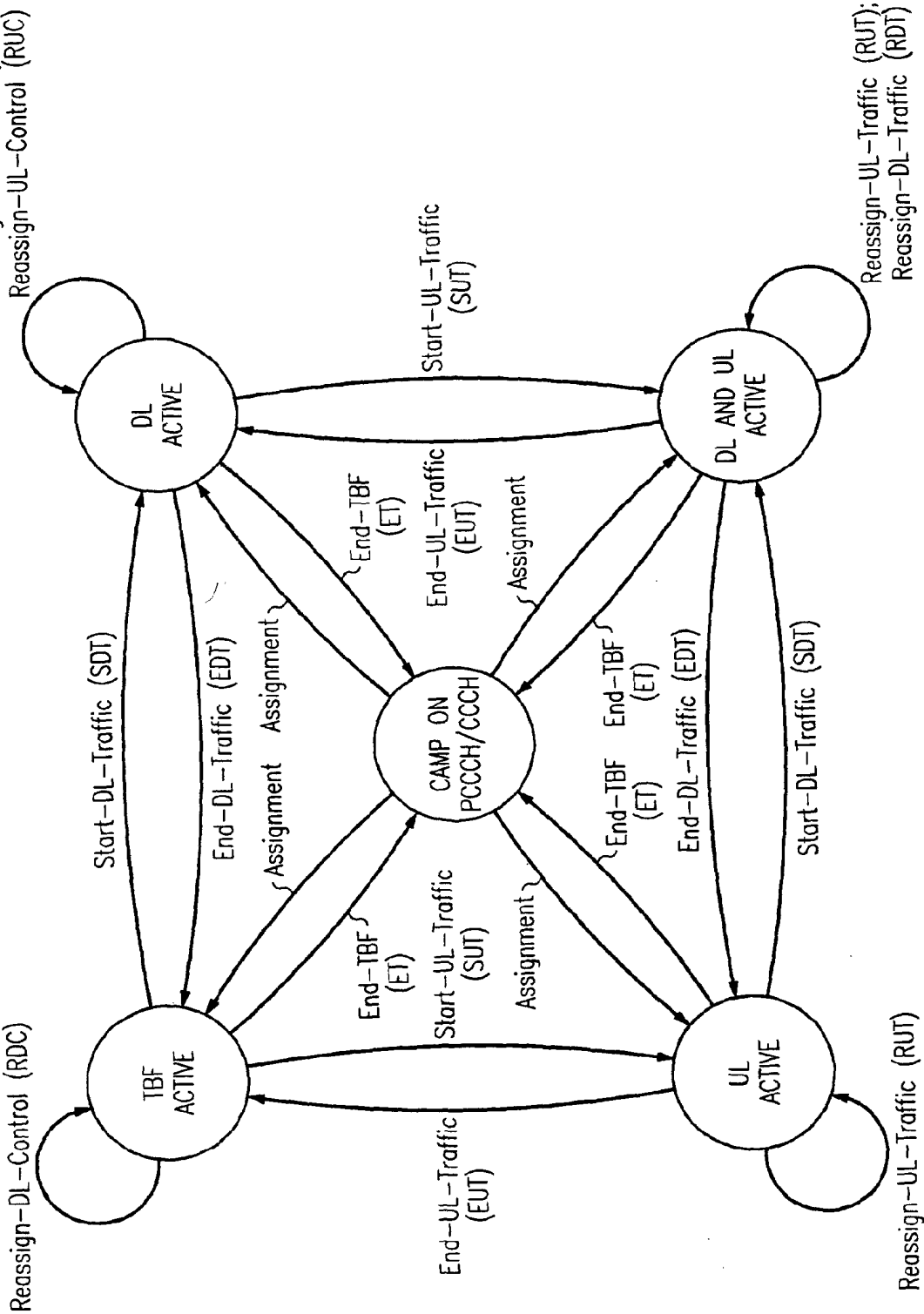
Reassign-DL-Traffic (RDT);
Reassign-UL-Control (RUC)
DL ACTIVE
Start-UL-Traffic (SUT)
DL AND UL ACTIVE
Reassign-UL-Traffic (RUT);
Reassign-DL-Traffic (RDT)
Start-DL-Traffic (SDT)
End-DL-Traffic (EDT)
Assignment
End-TBF (ET)
End-UL-Traffic (EUT)
Assignment
CAMP ON PCCCH/CCCH
End-TBF (ET)
End-DL-Traffic (EDT)
Start-DL-Traffic (SDT)
End-TBF (ET)
Start-UL-Traffic (SUT)
Assignment
TBF ACTIVE
UL ACTIVE
End-UL-Traffic (EUT)
Reassign-DL-Control (RDC)
Reassign-UL-Traffic (RUT)

FIG. 4

RT TBF STATE	TRAFFIC ACTIVITY		TCH CHANNEL ASSIGNMENT		CONTROL CHANNEL ASSIGNMENT	
	UL	DL	UL	DL	UL	DL
TBF Inactive	idle	idle			FRACH FACKCH UPRCH UBMCH	FASSCH DPRCH DBMCH
UL Active	active	idle	UTCH/ (B)FACCH/ MSACCH		FRACH FACKCH UBMCH	FASSCH DPRCH DBMCH
DL Active	idle	active		DTCH/ (B)FACCH/ MSACCH	FRACH FACKCH UPRCH UBMCH	FASSCH DBMCH
UL + DL Active	active	active	UTCH/ (B)FACCH/ MSACCH	DTCH/ (B)FACCH/ MSACCH	FRACH FACKCH UBMCH	FASSCH DBMCH

FIG. 5

PROCEDURES	RT TBF STATE			
	Inactive	UL Active	DL Active	DL + UL Active
Reassign DL Control (RDC)	X	X		
Reassign UL Control (RUC)	X		X	
Start DL Traffic (SDT)	X	X		
End DL Traffic (EDT)			X	X
Reassign DL Traffic (RDT)			X	X
Start UL Traffic (SUT)	X		X	
End UL Traffic (EUT)		X		X
Reassign UL Traffic (RUT)		X		X
End TBF (ET)	X	X	X	X
Start New TBF (ST)	X	X	X	X

FIG. 6

MESSAGE	CHANNEL DURING UPLINK TRAFFIC	CHANNEL WITH NO UPLINK TRAFFIC
Access Request	BFACCH	FRACH
Acknowledge to Assignment	BFACCH	FACKCH
AMR Mode Request	UTCH	UPRCH
SID Update	N/A	UPRCH
Neighbor Measurement Report	MSACCH	UPRCH
RLC Signaling	UTCH	UBMCH
End TBF Request	BFACCH	FRACH

FIG. 7

MESSAGE	CHANNEL DURING DOWNLINK TRAFFIC	CHANNEL WITH NO DOWNLINK TRAFFIC
Assignment (all)	BFACCH	FASSCH
AMR Mode Command	DTCH	DPRCH
SID Update	N/A	DPRCH
Handover Directives	FACCH	DBMCH
RLC Signaling	DTCH	DBMCH
Timing Advance	MSACCH	DPRCH
Power Control	MSACCH	DPRCH
End TBF Command	BFACCH	FASSCH

FIG. 8

DOWNLINK BURST MESSAGE	INFORMATION ELEMENTS
Assign UTCH	ARI, DMT, TBFI, CID, CTS, PH, SD
Deferred Assign UTCH	ARI, DMT, TBFI, RRBP, delay
Assign DTCH	ARI, DMT, TBFI, RRBP, CID, CTS, PH, SD
Assign UPRCH	ARI, DMT, RRBP, CID, CTS, OFF
Assign DPRCH	ARI, DMT, RRBP, CID, CTS, OFF
Assign FRACH	ARI, DMT, RRBP, CID, CTS, PH
Assign FACKCH	ARI, DMT, RRBP, CID, CTS, PH
Assign FASSCH	ARI, DMT, RRBP, CID, CTS, PH
End TBF Command	ARI, DMT, TBFI, RRBP, reason

FIG. 9

UPLINK BURST MESSAGE	INFORMATION ELEMENTS
Access Request	ARI, UMT, TBFI
Acknowledge UTCH	ARI, UMT, TBFI
Acknowledge DTCH	ARI, UMT, TBFI
Acknowledge UPRCH	ARI, UMT, TBFI
Acknowledge DPRCH	ARI, UMT, TBFI
Acknowledge FRACH	ARI, UMT, TBFI
Acknowledge FACKCH	ARI, UMT, TBFI
Acknowledge FASSCH	ARI, UMT, TBFI
Acknowledge End TBF	ARI, UMT, TBFI
End TBF Request	ARI, UMT, TBFI, reason

FIG. 10

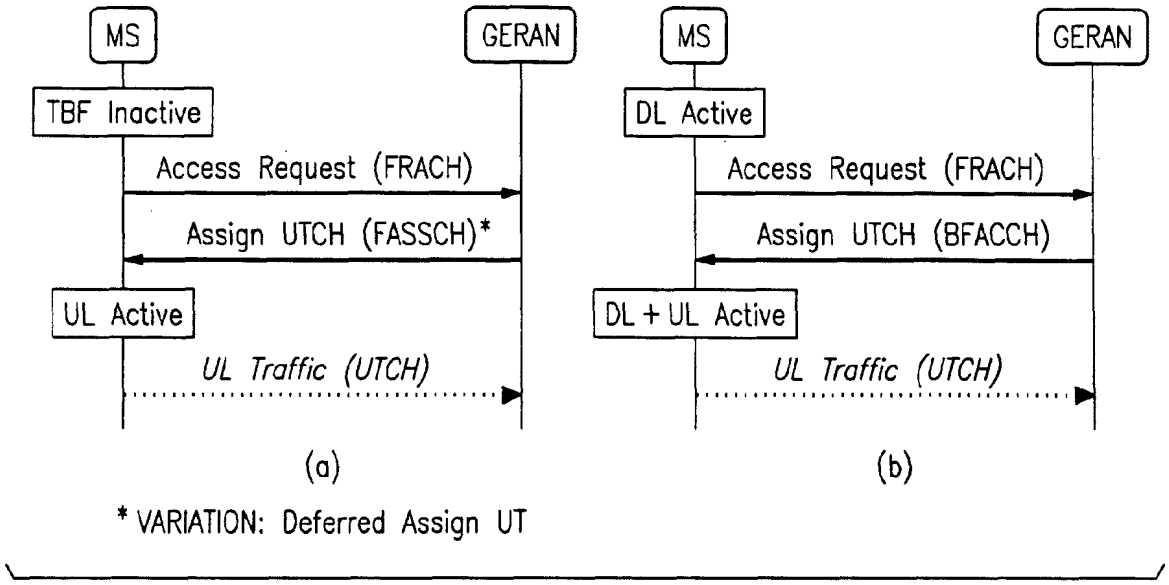
MS
GERAN
TBF Inactive
Access Request (FRACH)
Assign UTCH (FASSCH)*
UL Active
UL Traffic (UTCH)
(a)
MS
GERAN
DL Active
Access Request (FRACH)
Assign UTCH (BFACCH)
DL + UL Active
UL Traffic (UTCH)
(b)
* VARIATION: Deferred Assign UT

FIG. 11

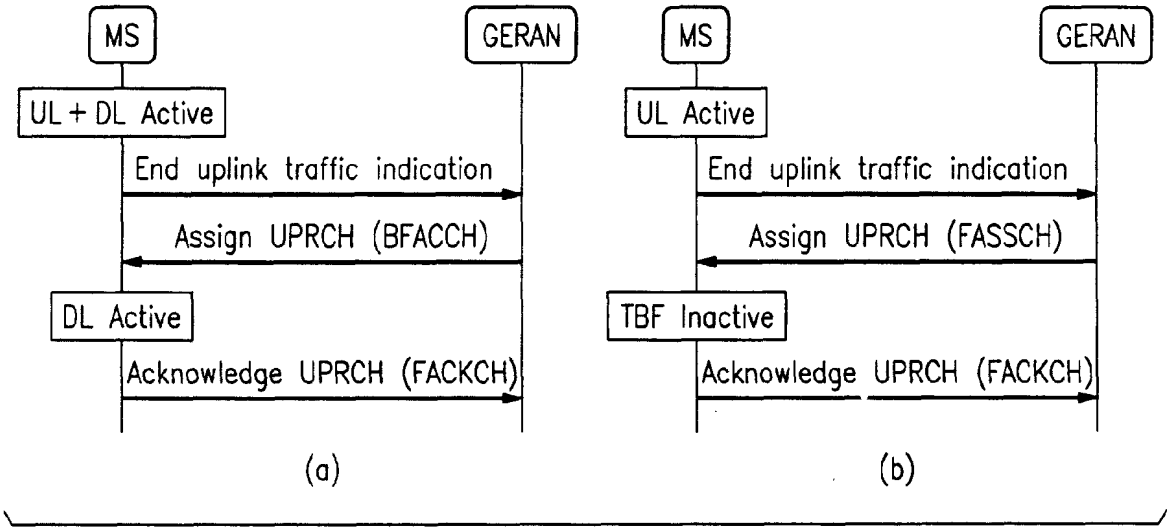
MS
GERAN
UL + DL Active
End uplink traffic indication
Assign UPRCH (BFACCH)
DL Active
Acknowledge UPRCH (FACKCH)
(a)
MS
GERAN
UL Active
End uplink traffic indication
Assign UPRCH (FASSCH)
TBF Inactive
Acknowledge UPRCH (FACKCH)
(b)

FIG. 12

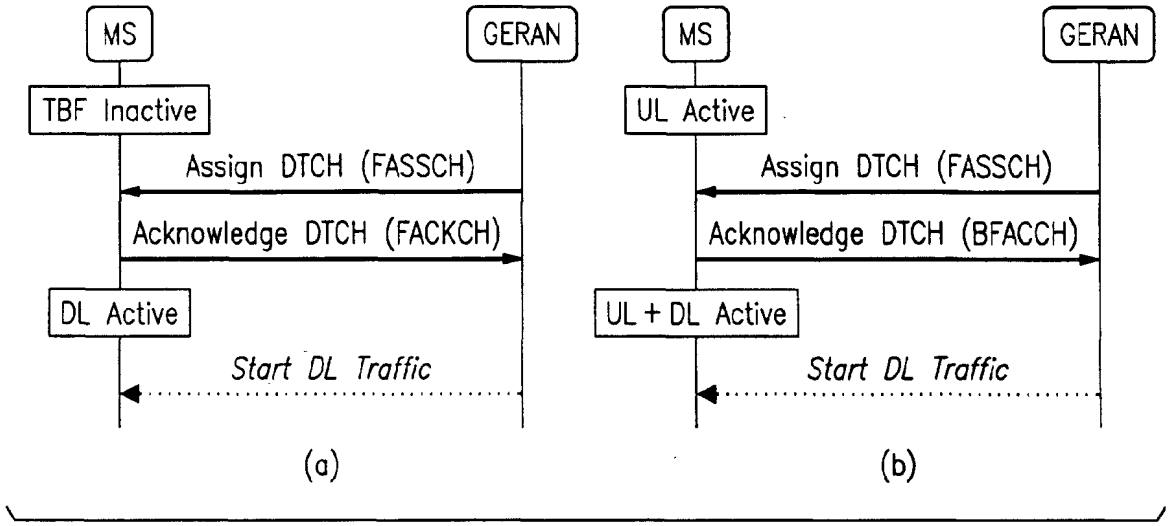
MS
GERAN
TBF Inactive
Assign DTCH (FASSCH)
Acknowledge DTCH (FACKCH)
DL Active
Start DL Traffic
(a)
MS
GERAN
UL Active
Assign DTCH (FASSCH)
Acknowledge DTCH (BFACCH)
UL + DL Active
Start DL Traffic
(b)

FIG. 13

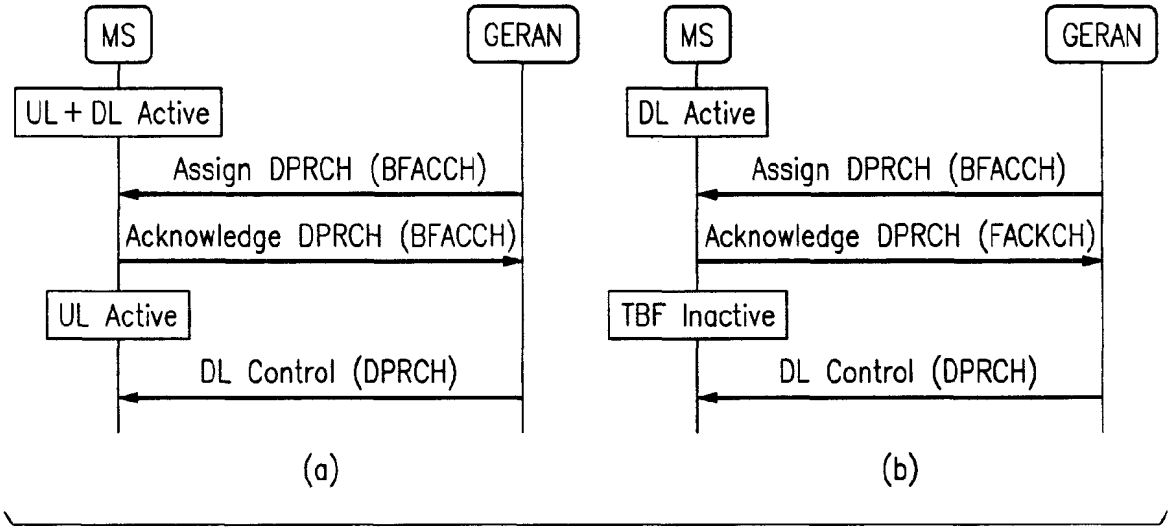
MS
GERAN
UL + DL Active
Assign DPRCH (BFACCH)
Acknowledge DPRCH (BFACCH)
UL Active
DL Control (DPRCH)
(a)
MS
GERAN
DL Active
Assign DPRCH (BFACCH)
Acknowledge DPRCH (FACKCH)
TBF Inactive
DL Control (DPRCH)
(b)

FIG. 14

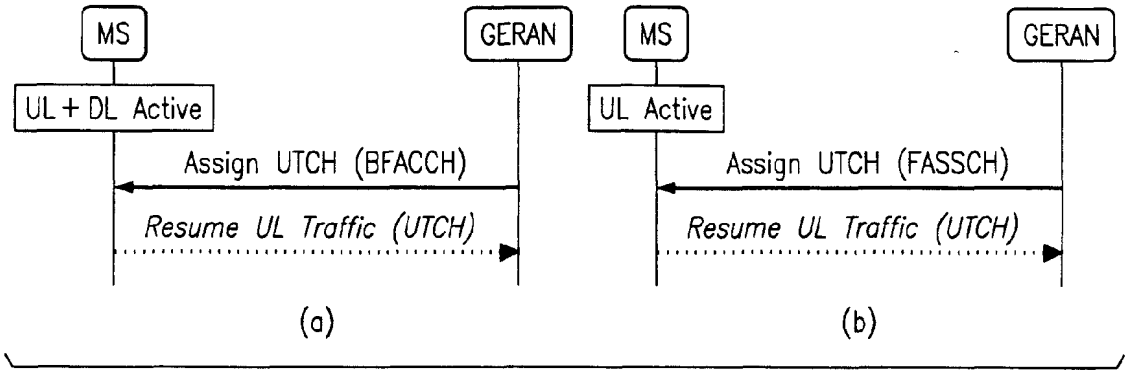

FIG. 15

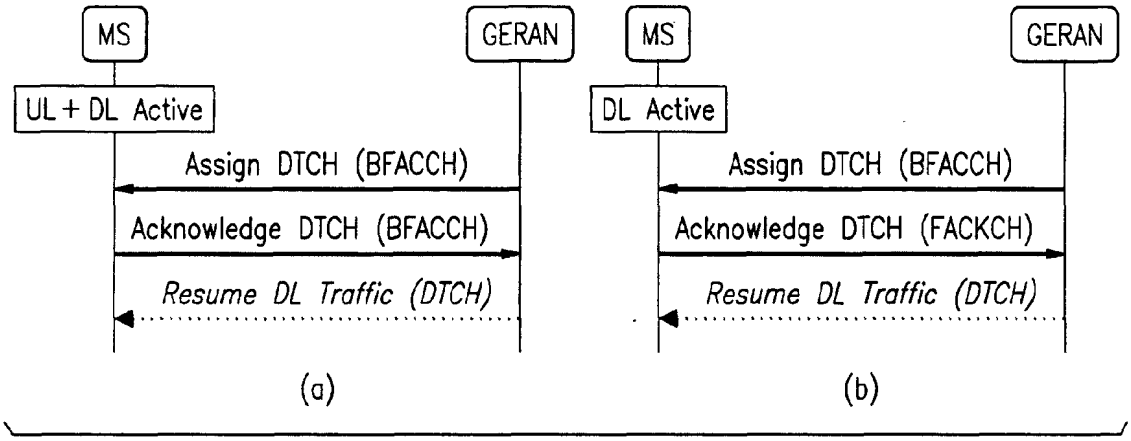

FIG. 16

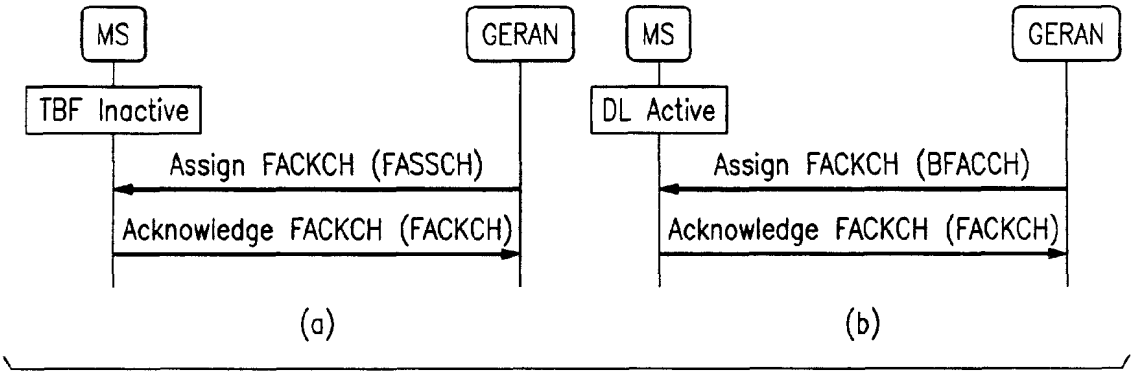

FIG. 17

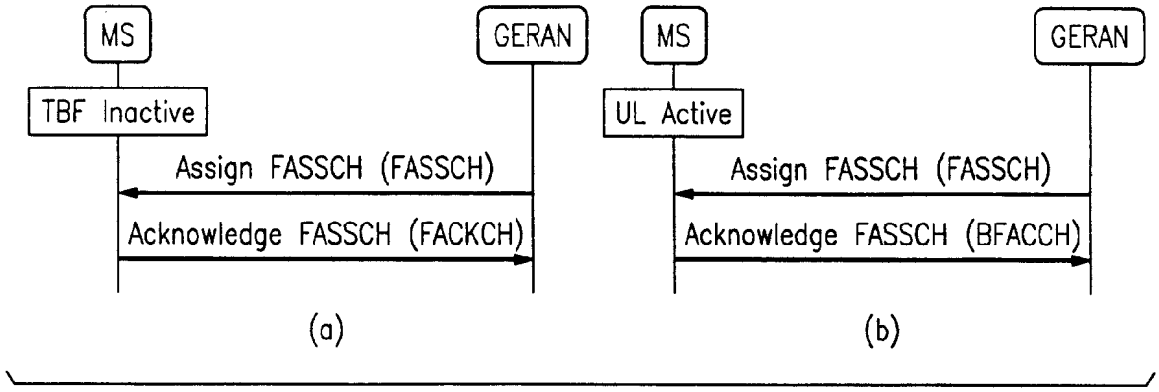
MS
GERAN
TBF Inactive
Assign FASSCH (FASSCH)
Acknowledge FASSCH (FACKCH)
(a)
MS
GERAN
UL Active
Assign FASSCH (FASSCH)
Acknowledge FASSCH (BFACCH)
(b)

FIG. 18

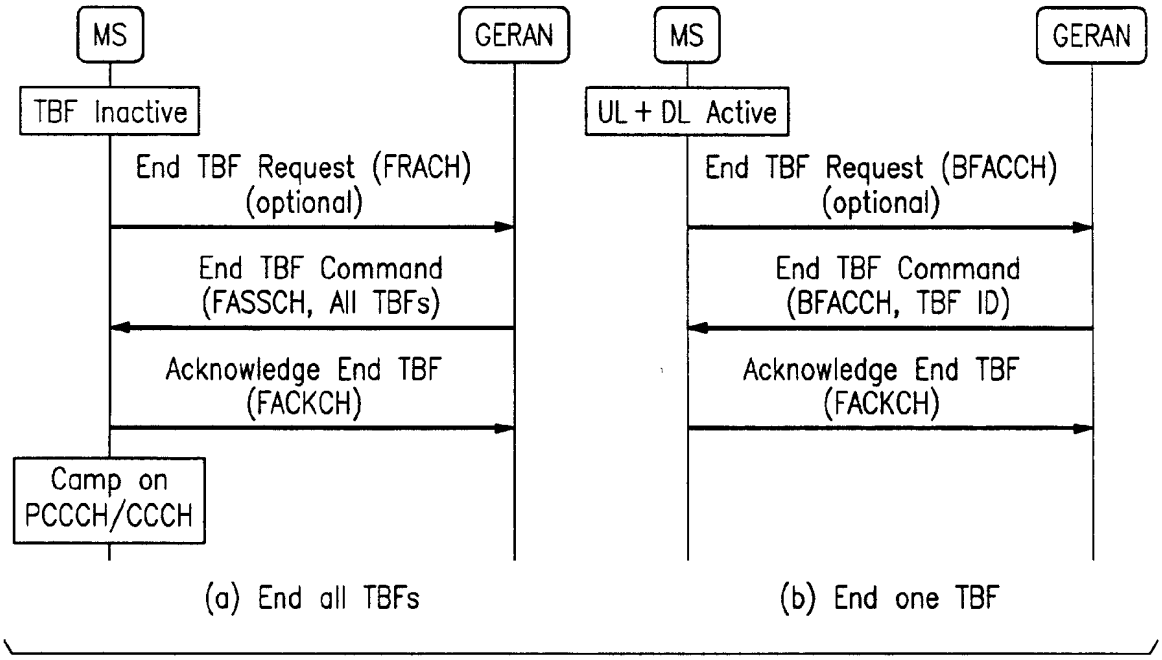
MS
GERAN
TBF Inactive
End TBF Request (FRACH)
(optional)
End TBF Command
(FASSCH, All TBFs)
Acknowledge End TBF
(FACKCH)
Camp on
PCCCH/CCCH
(a) End all TBFs
MS
GERAN
UL + DL Active
End TBF Request (BFACCH)
(optional)
End TBF Command
(BFACCH, TBF ID)
Acknowledge End TBF
(FACKCH)
(b) End one TBF

FIG. 19

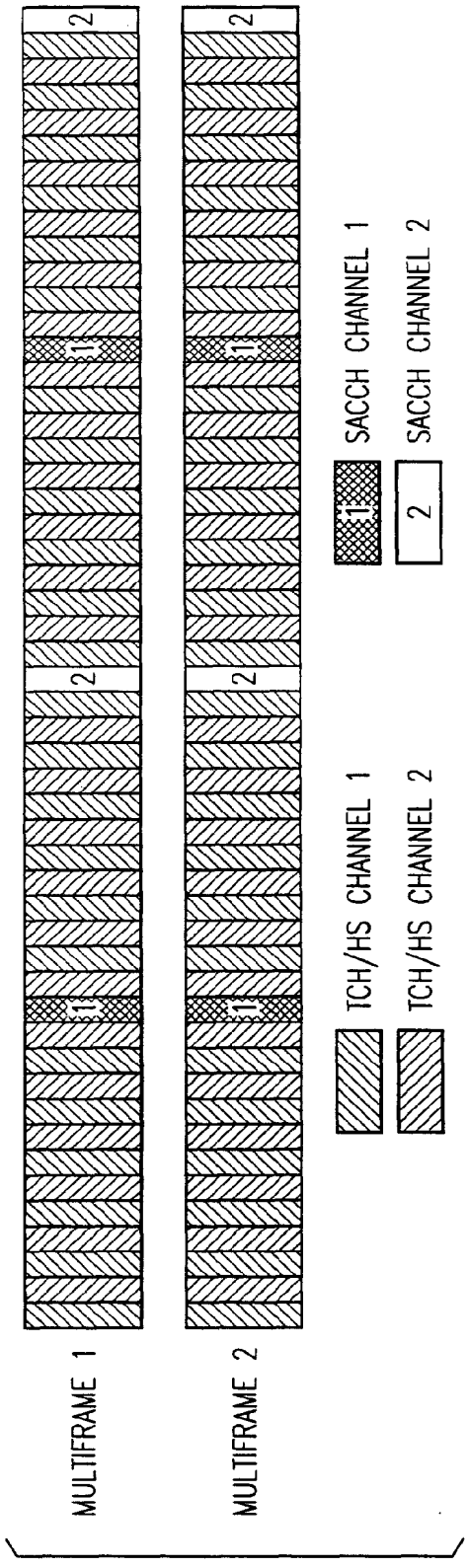
MULTIFRAME 1
MULTIFRAME 2
TCH/HS CHANNEL 1
TCH/HS CHANNEL 2
SACCH CHANNEL 1
SACCH CHANNEL 2

FIG. 20

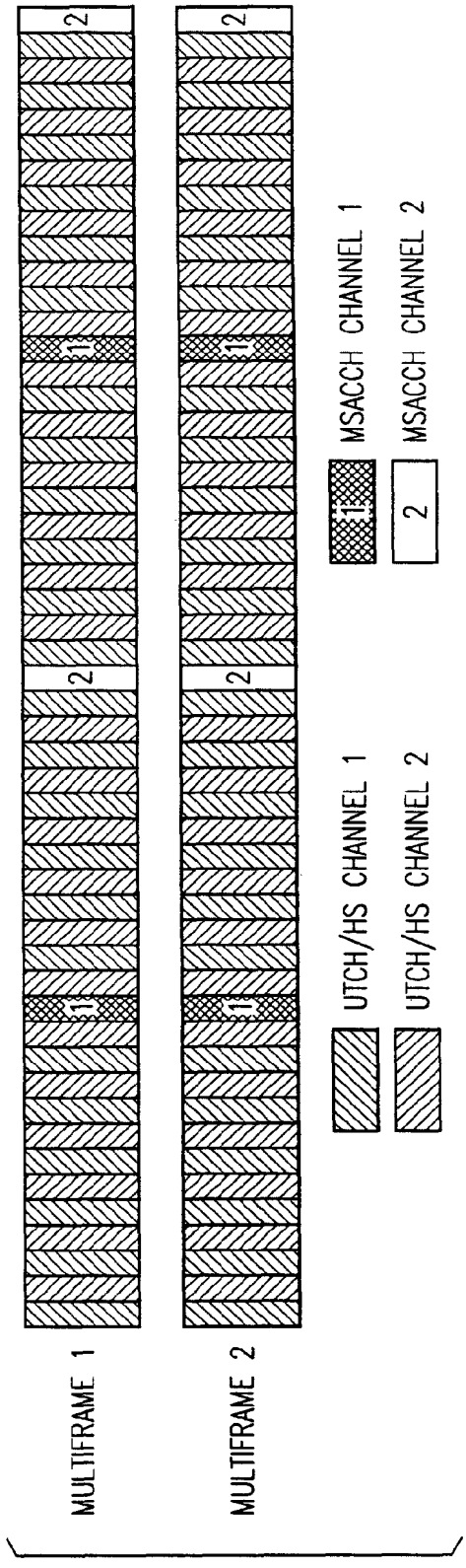
MULTIFRAME 1
MULTIFRAME 2
UTCH/HS CHANNEL 1
UTCH/HS CHANNEL 2
MSACCH CHANNEL 1
MSACCH CHANNEL 2

FIG. 21

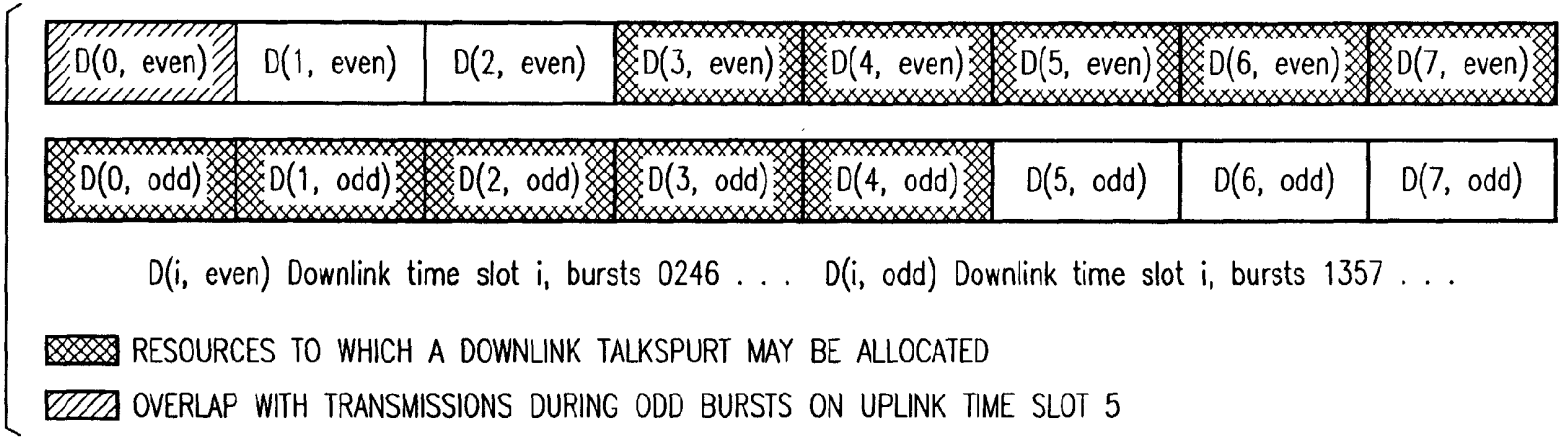
D(0, even)
D(1, even)
D(2, even)
D(3, even)
D(4, even)
D(5, even)
D(6, even)
D(7, even)
D(0, odd)
D(1, odd)
D(2, odd)
D(3, odd)
D(4, odd)
D(5, odd)
D(6, odd)
D(7, odd)
D(i, even) Downlink time slot i, bursts 0246 . . . D(i, odd) Downlink time slot i, bursts 1357 . . .
RESOURCES TO WHICH A DOWNLINK TALKSPURT MAY BE ALLOCATED
OVERLAP WITH TRANSMISSIONS DURING ODD BURSTS ON UPLINK TIME SLOT 5

FIG. 22

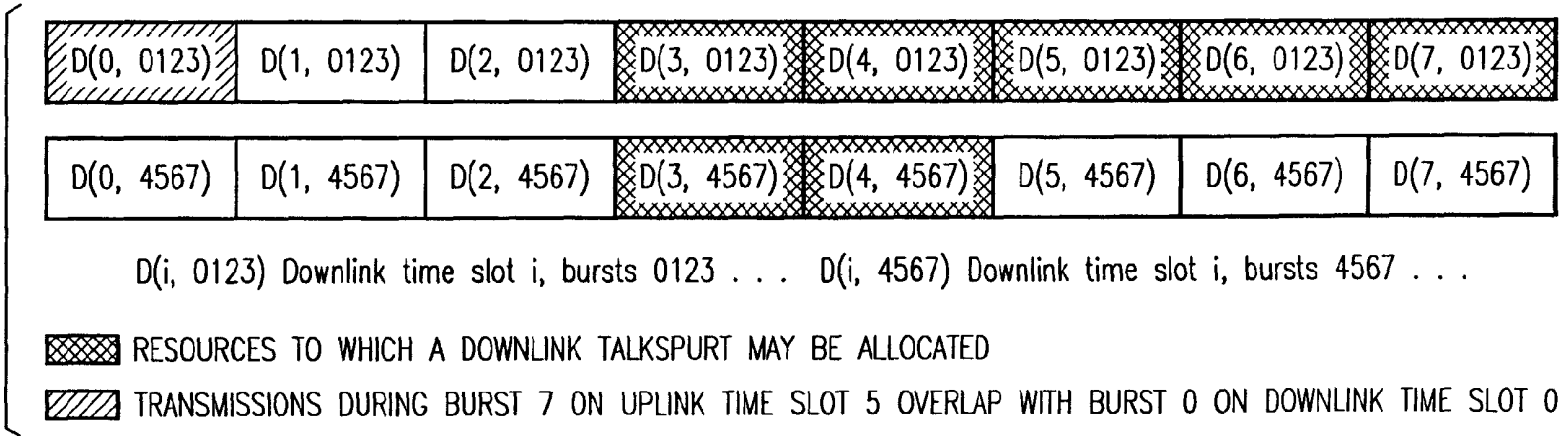
D(0, 0123)
D(1, 0123)
D(2, 0123)
D(3, 0123)
D(4, 0123)
D(5, 0123)
D(6, 0123)
D(7, 0123)
D(0, 4567)
D(1, 4567)
D(2, 4567)
D(3, 4567)
D(4, 4567)
D(5, 4567)
D(6, 4567)
D(7, 4567)
D(i, 0123) Downlink time slot i, bursts 0123 . . . D(i, 4567) Downlink time slot i, bursts 4567 . . .
RESOURCES TO WHICH A DOWNLINK TALKSPURT MAY BE ALLOCATED
TRANSMISSIONS DURING BURST 7 ON UPLINK TIME SLOT 5 OVERLAP WITH BURST 0 ON DOWNLINK TIME SLOT 0

FIG. 23

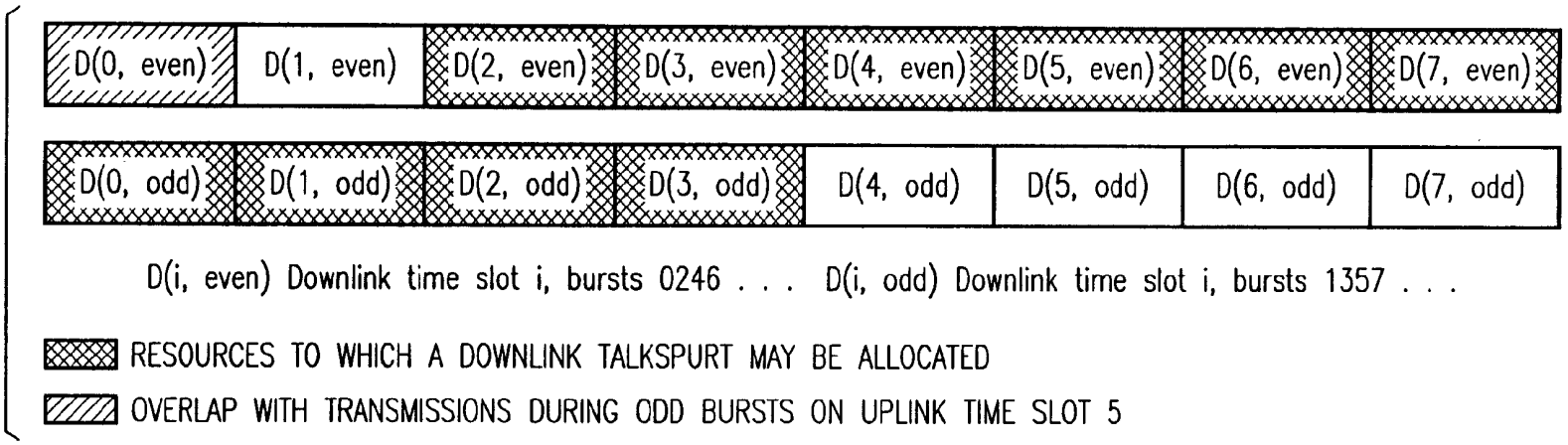

FIG. 24

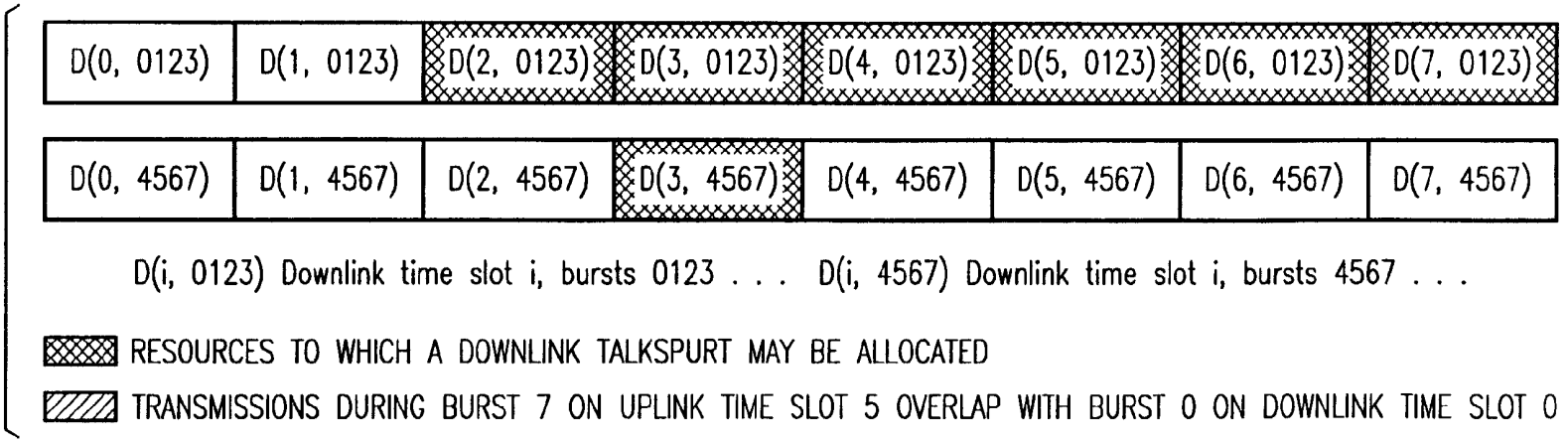

FIG. 25

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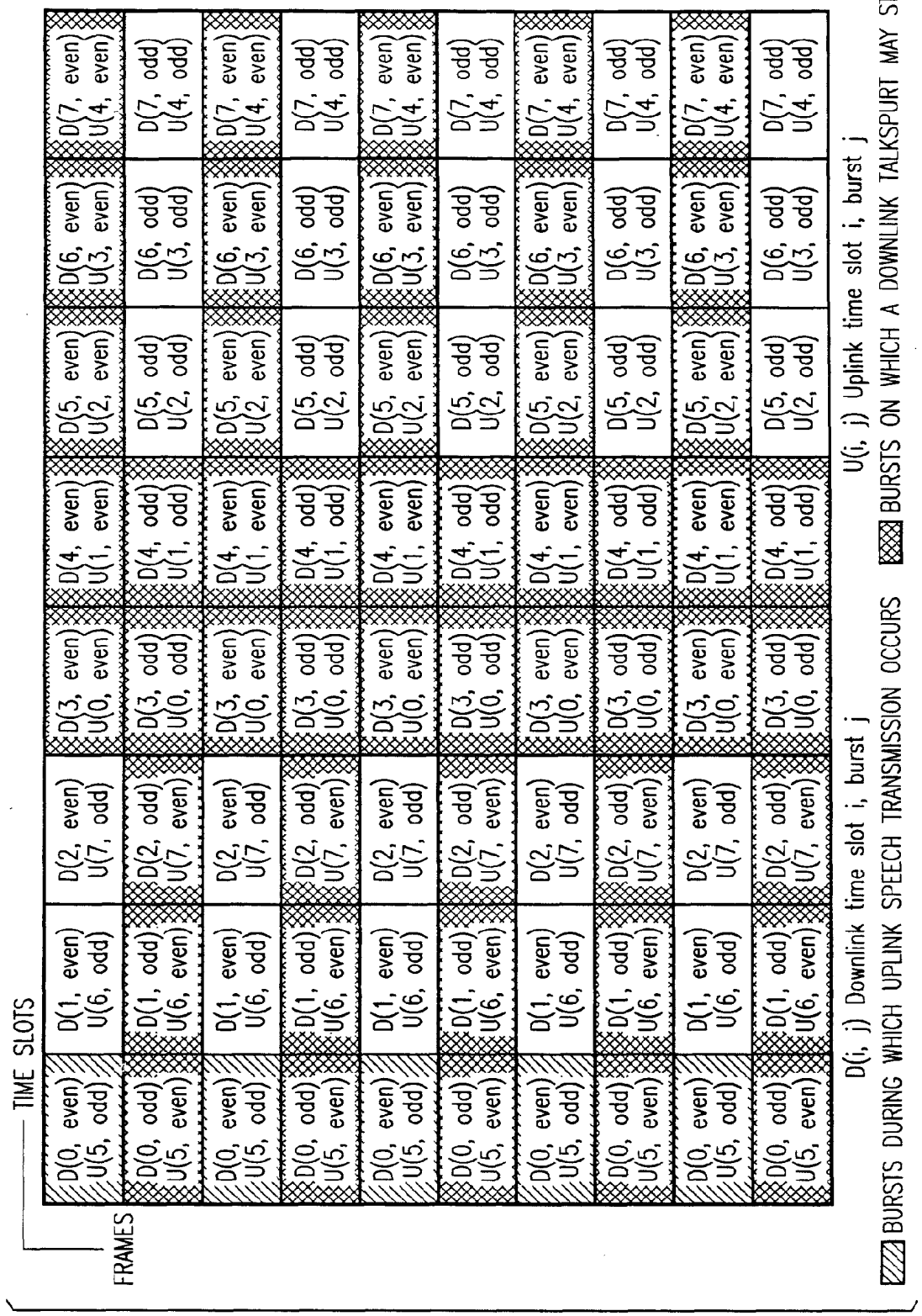
TIME SLOTS
FRAMES
D(0, even) U(5, odd)
D(1, even) U(6, odd)
D(2, even) U(7, odd)
D(3, even) U(0, even)
D(4, even) U(1, even)
D(5, even) U(2, even)
D(6, even) U(3, even)
D(7, even) U(4, even)
D(0, odd) U(5, even)
D(1, odd) U(6, even)
D(2, odd) U(7, even)
D(3, odd) U(0, odd)
D(4, odd) U(1, odd)
D(5, odd) U(2, odd)
D(6, odd) U(3, odd)
D(7, odd) U(4, odd)
D(i, j) Downlink time slot i, burst j
U(i, j) Uplink time slot i, burst j
BURSTS DURING WHICH UPLINK SPEECH TRANSMISSION OCCURS
BURSTS ON WHICH A DOWNLINK TALKSPURT MAY START

FIG. 26

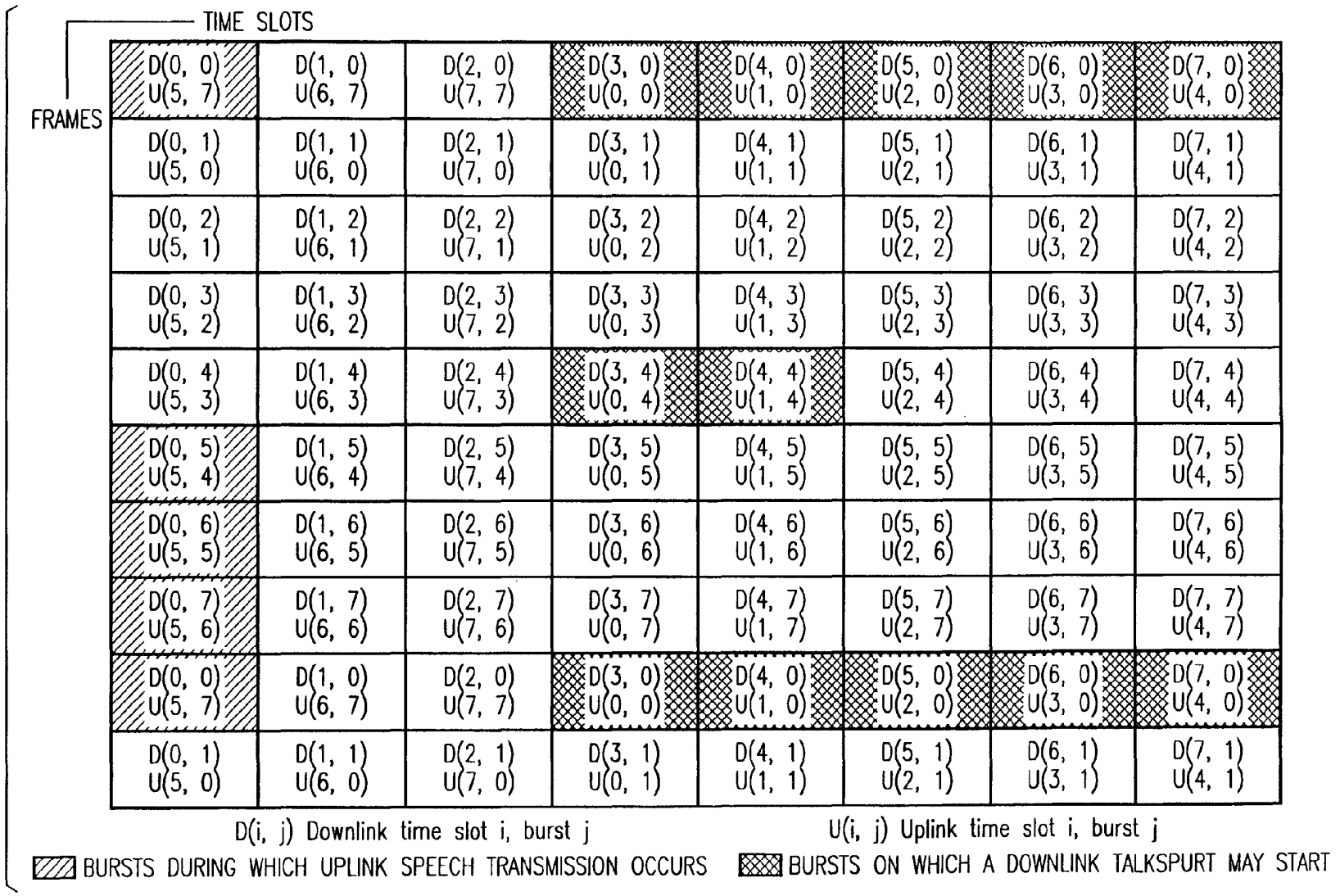
TIME SLOTS
FRAMES
D(0, 0) U(5, 7)
D(1, 0) U(6, 7)
D(2, 0) U(7, 7)
D(3, 0) U(0, 0)
D(4, 0) U(1, 0)
D(5, 0) U(2, 0)
D(6, 0) U(3, 0)
D(7, 0) U(4, 0)
D(0, 1) U(5, 0)
D(1, 1) U(6, 0)
D(2, 1) U(7, 0)
D(3, 1) U(0, 1)
D(4, 1) U(1, 1)
D(5, 1) U(2, 1)
D(6, 1) U(3, 1)
D(7, 1) U(4, 1)
D(0, 2) U(5, 1)
D(1, 2) U(6, 1)
D(2, 2) U(7, 1)
D(3, 2) U(0, 2)
D(4, 2) U(1, 2)
D(5, 2) U(2, 2)
D(6, 2) U(3, 2)
D(7, 2) U(4, 2)
D(0, 3) U(5, 2)
D(1, 3) U(6, 2)
D(2, 3) U(7, 2)
D(3, 3) U(0, 3)
D(4, 3) U(1, 3)
D(5, 3) U(2, 3)
D(6, 3) U(3, 3)
D(7, 3) U(4, 3)
D(0, 4) U(5, 3)
D(1, 4) U(6, 3)
D(2, 4) U(7, 3)
D(3, 4) U(0, 4)
D(4, 4) U(1, 4)
D(5, 4) U(2, 4)
D(6, 4) U(3, 4)
D(7, 4) U(4, 4)
D(0, 5) U(5, 4)
D(1, 5) U(6, 4)
D(2, 5) U(7, 4)
D(3, 5) U(0, 5)
D(4, 5) U(1, 5)
D(5, 5) U(2, 5)
D(6, 5) U(3, 5)
D(7, 5) U(4, 5)
D(0, 6) U(5, 5)
D(1, 6) U(6, 5)
D(2, 6) U(7, 5)
D(3, 6) U(0, 6)
D(4, 6) U(1, 6)
D(5, 6) U(2, 6)
D(6, 6) U(3, 6)
D(7, 6) U(4, 6)
D(0, 7) U(5, 6)
D(1, 7) U(6, 6)
D(2, 7) U(7, 6)
D(3, 7) U(0, 7)
D(4, 7) U(1, 7)
D(5, 7) U(2, 7)
D(6, 7) U(3, 7)
D(7, 7) U(4, 7)
D(0, 0) U(5, 7)
D(1, 0) U(6, 7)
D(2, 0) U(7, 7)
D(3, 0) U(0, 0)
D(4, 0) U(1, 0)
D(5, 0) U(2, 0)
D(6, 0) U(3, 0)
D(7, 0) U(4, 0)
D(0, 1) U(5, 0)
D(1, 1) U(6, 0)
D(2, 1) U(7, 0)
D(3, 1) U(0, 1)
D(4, 1) U(1, 1)
D(5, 1) U(2, 1)
D(6, 1) U(3, 1)
D(7, 1) U(4, 1)
D(i, j) Downlink time slot i, burst j
U(i, j) Uplink time slot i, burst j
BURSTS DURING WHICH UPLINK SPEECH TRANSMISSION OCCURS
BURSTS ON WHICH A DOWNLINK TALKSPURT MAY START

FIG. 27

SPEECH FRAME NUMBER	0246/1357 INTERLEAVING		0123/4567 INTERLEAVING	
	ARRIVAL AT RECEIVER (ms)	PLAY OUT (ms)	ARRIVAL AT RECEIVER (ms)	PLAY OUT (ms)
0	9.23	14	13.845	14
1	27.69	34	13.845	34
2	46.15	54	50.765	54
3	73.84	74	50.765	74
4	92.3	94	92.3	94
5	110.76	114	92.3	114
6	129.22	134	133.835	134

TABLE: SPEECH FRAME ARRIVALS AND PLAY OUT INSTANTS WITH DIFFERENT INTERLEAVING APPROACHES; THE END OF BURST 0 OCCURS AT 0.0 ms.

FIG. 28

CHANNEL	INTERLEAVING	VOCODER RATE	CODING RATE	C/I (dB) FOR 1% FER	
				i FH	no FH
TU3	0246/1357	7.4 EEP	0.41	13.15	**18.8**
	0123/4567	7.4 EEP	0.41	13.1	19.8
BU100	0246/1357	7.4 EEP	0.41	13.5	**13.1**
	0123/4567	7.4 EEP	0.41	13.3	13.5
HT100	0246/1357	7.4 EEP	0.41	14.7	**15.5**
	0123/4567	7.4 EEP	0.41	14.9	16.3

TABLE: PERFORMANCE OF THE TWO INTERLEAVING SCHEMES WITH QPSK MODULATION.

FIG. 29

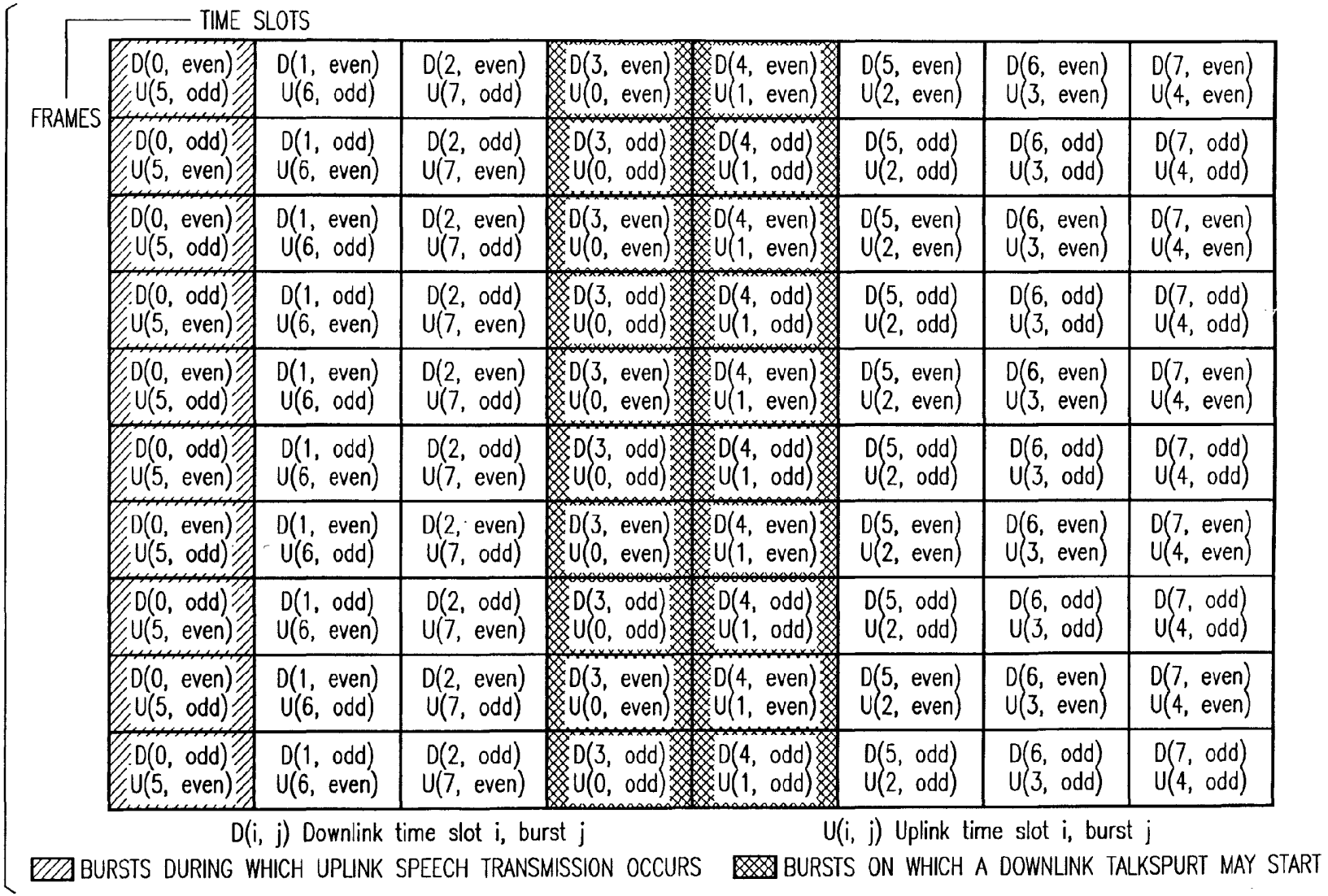
TIME SLOTS
FRAMES
D(0, even) U(5, odd)
D(1, even) U(6, odd)
D(2, even) U(7, odd)
D(3, even) U(0, even)
D(4, even) U(1, even)
D(5, even) U(2, even)
D(6, even) U(3, even)
D(7, even) U(4, even)
D(0, odd) U(5, even)
D(1, odd) U(6, even)
D(2, odd) U(7, even)
D(3, odd) U(0, odd)
D(4, odd) U(1, odd)
D(5, odd) U(2, odd)
D(6, odd) U(3, odd)
D(7, odd) U(4, odd)
D(i, j) Downlink time slot i, burst j
U(i, j) Uplink time slot i, burst j
BURSTS DURING WHICH UPLINK SPEECH TRANSMISSION OCCURS
BURSTS ON WHICH A DOWNLINK TALKSPURT MAY START

FIG. 30

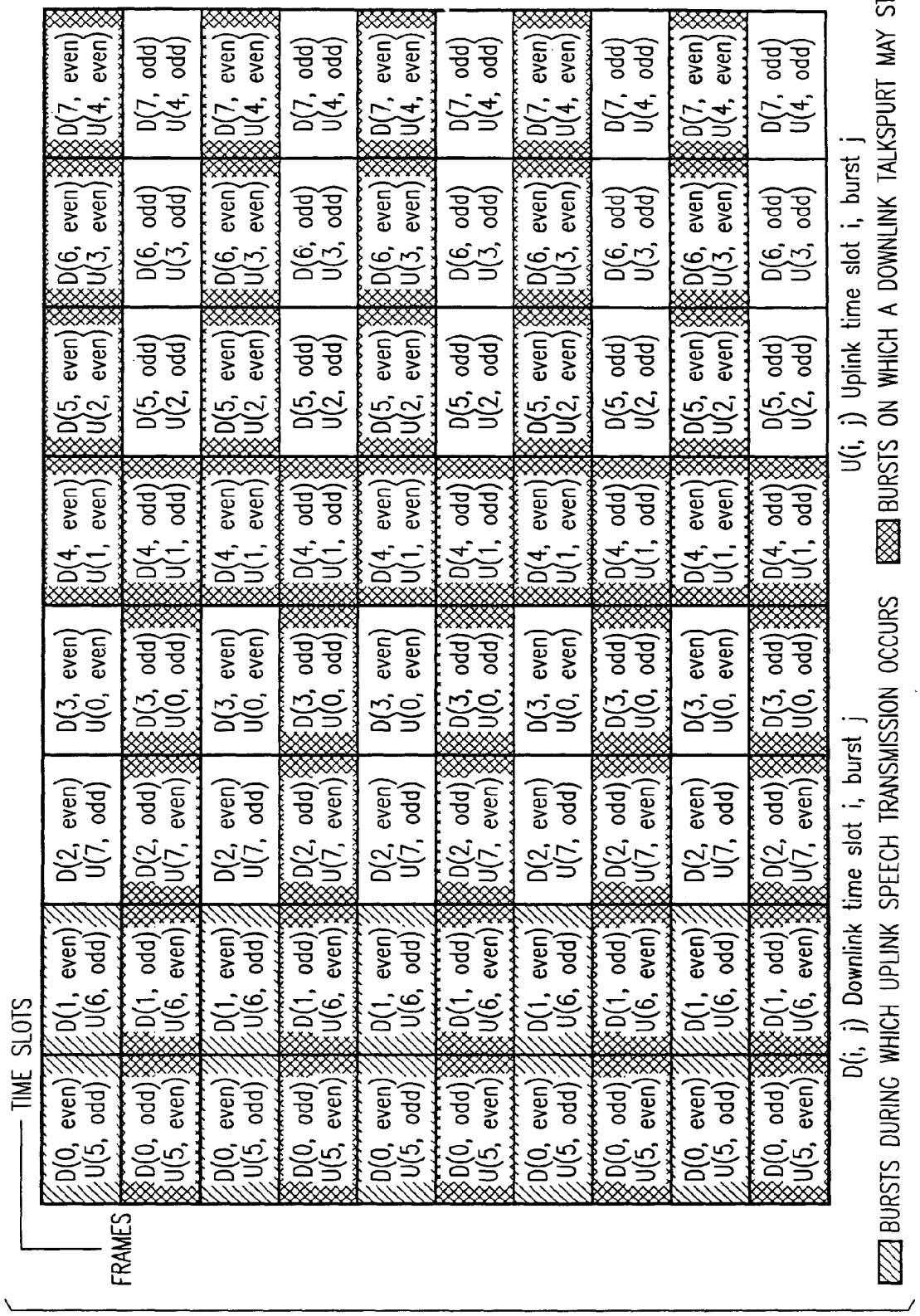
TIME SLOTS
FRAMES
D(0, even) U(5, odd)
D(1, even) U(6, odd)
D(2, even) U(7, odd)
D(3, even) U(0, even)
D(4, even) U(1, even)
D(5, even) U(2, even)
D(6, even) U(3, even)
D(7, even) U(4, even)
D(i, j) Downlink time slot i, burst j
U(i, j) Uplink time slot i, burst j
BURSTS DURING WHICH UPLINK SPEECH TRANSMISSION OCCURS
BURSTS ON WHICH A DOWNLINK TALKSPURT MAY START

FIG. 31